A Study to Assess the Outcome of Non-Invasive Bubble CPAP in the Management of Respiratory Distress in Neonates

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Abstract: ***Introduction**: The neonatal period, encompassing the first 28 days of life, is the most critical for a child's survival. Respiratory distress is a major cause of neonatal morbidity and mortality, with neonatal respiratory distress syndrome being the most common aetiology, particularly in preterm infants. Despite advancements in neonatal care, including antenatal corticosteroids and surfactant therapy, respiratory distress remains a significant challenge, necessitating effective and accessible non - invasive respiratory support. **Aim and Objectives**: This study evaluates the clinical outcomes of neonates managed with bubble continuous positive airway pressure, focusing on its role in reducing respiratory distress severity, minimising NICU stay, and identifying factors influencing treatment success. **Methodology**: This is a prospective observational study which was conducted at the Neonatal Intensive Care Unit of our institute from May 2023 to April 2025. The study included 150 neonates with moderate respiratory distress, defined by a Downes' Score of 4 to 6 and oxygen saturation (SpO_2) below 90% despite supplemental oxygen. Neonates with severe respiratory distress (Downes' Score >7), major congenital anomalies, or requiring immediate invasive ventilation were excluded. Data collection included maternal and neonatal history, mode of delivery, antenatal steroid administration, respiratory distress severity, and bCPAP response. Neonates were closely monitored, and statistical analysis was performed using SPSS version 20, with $p<0.05$ considered statistically significant. **Results**: The study population consisted of 150 neonates, with a male predominance (58.7). Respiratory distress syndrome was the most common diagnosis (70.0%), followed by birth asphyxia (16.0%), meconium aspiration syndrome (12.0%), and congenital pneumonia (2.0%). The Downes' Score strongly predicted respiratory distress severity, with higher scores correlating with increased mechanical ventilation need and prolonged NICU stay. Neonates requiring bCPAP for >24 hours had higher ventilation rates, while those on bCPAP for <12 hours had significantly better outcomes. The overall survival rate was 81.3%, and 18.7% required mechanical ventilation. **Conclusion**: The study highlights the efficacy of bCPAP as a first - line respiratory support in neonates with moderate respiratory distress. Early initiation of bCPAP, appropriate PEEP settings, and complete antenatal steroid administration significantly improved outcomes, reducing the need for mechanical ventilation and prolonged NICU stay.***

Keywords: neonatal respiratory distress, bubble CPAP, Downe's score, NICU outcomes, antenatal steroids

1. Introduction

The neonatal period, encompassing the first 28 days of life, is the most critical for a child's survival. In 2022, the global neonatal mortality rate was 17 deaths per 1, 000 live births. In total, 2.3 million neonatal deaths occurred globally in 2022, approximately 6, 300 deaths daily. [1]

The Neonatal Mortality Rate is defined as the number of deaths during the first 28 completed days of life per 1000 live births in a specified period. According to UNICEF report in 2021 in India, the baseline neonatal mortality rate (NMR) stands at 23 deaths per 1, 000 live births. [2]

Neonatal respiratory distress syndrome (RDS) is a significant cause of respiratory distress in newborns, typically occurring within hours of birth, often immediately after delivery. It predominantly affects preterm infants, with its incidence inversely related to gestational age. The condition is more severe in those born at earlier gestational ages. Despite advances in treatment, such as antenatal corticosteroids, surfactant therapy, and enhanced respiratory support, RDS remains a major contributor to morbidity and mortality among preterm neonates. [3] Respiratory distress (RD) in neonates is characterized by an increased work of breathing (WOB), presenting as tachypnea, grunting, chest retractions, and often accompanied by diminished air entry and cyanosis. [4] It is one of the most prevalent conditions in new - borns globally, affecting 3 - 7% of all live births. [5 - 8] In cases of respiratory distress, prompt and appropriate interventions, such as effective resuscitation, oxygen therapy, temperature regulation, timely referral, and adequate ventilator support, are crucial in minimizing both mortality and morbidity.

Continuous Positive Airway Pressure (CPAP) was first utilized in 1971 by Gregory et al. as a preventive measure against respiratory distress in preterm neonates. Subsequently, Dr. Jen - Tien Wung, introduced Bubble CPAP using nasal prongs. [9] In 1987, Avery et al. conducted a retrospective study involving 1, 625 neonates across eight tertiary care centres, demonstrating that nasal CPAP significantly reduced the incidence of chronic lung disease without a substantial impact on overall mortality. [10]

Bubble CPAP (bCPAP) offers several advantages over other CPAP modalities (Figure 1), particularly in neonates. (Figure

1) It is a cost - effective and technologically simple respiratory support system, making it highly suitable for resource - limited settings, such as low - and middle - income countries (LMICs). Clinical studies have demonstrated that bCPAP significantly reduces neonatal mortality, decreases the need for mechanical ventilation by 30%–50%, and lowers extubation failure rates. Additionally, trials comparing bCPAP with ventilator CPAP show similar mortality and complication rates, with bCPAP exhibiting a lower CPAP failure rate. Its simplicity and effectiveness highlight its role in improving neonatal respiratory care. [12, 13]

2. Materials and Methods

Study design: This was a prospective observational study in which participants were observed over time to assess outcomes without any intervention or manipulation of exposure, held at our institute over a period of 2 years i. e. May 2023 - April 2025

Study population: Neonates admitted to the Neonatal Intensive Care Unit (NICU) for respiratory distress during the study period who met the inclusion criteria.

Inclusion Criteria:
1) Neonates with respiratory distress (Downes' Score 4 to 6)
2) Neonates with oxygen saturation (SpO_2) < 90% even with supplemental oxygen

Exclusion Criteria:
1) Babies with severe respiratory distress (Downes' score > 7/10)
2) Unstable cardiovascular status
3) Prolonged and refractory seizures
4) Major congenital anomalies, including:
- Tracheoesophageal fistula
- Diaphragmatic hernia
- Choanal atresia
- Gastroschisis
- Pneumothorax without chest drain

Sample Size: The sample size was calculated using the formula $n=z^2\alpha \times P \times (Q) / d^2$. Where, n = required sample size with prevalence (p) = 0.036, q = 0.964, standard error = 3% (0.03), and z = 1.96 at 95% CI. Therefore, $n=z^2\alpha \times P \times (Q) / d^2$ = 1.96 x 1.96 x 0.036 x 0.964 / (0.03) 2 n = 148 (approximately 150 patients). The final sample size is **150 neonates**, ensuring a statistically robust analysis while remaining feasible for the study's timeframe and resources.

Data Collection Details: Data collection for this study was conducted by the observer, using a designated study proforma. Prior to participation, eligible parent/guardian was briefed about the study in their local vernacular language, and written informed consent was obtained through a pre - approved proforma sanctioned by our ethical committee, with the option to withdraw at any time without penalties. A detailed history was recorded, taken from subject's mother which included mode of delivery, history of antenatal steroids, intranatal history, immediate postnatal history, maternal history, and congenital anomalies. Respiratory distress was assessed using Downes' score.
- A score of 4 - 7 indicates CPAP application.
- A score >7 indicates impending respiratory failure, requiring intubation and mechanical ventilation.

Date and time of CPAP application was noted. Necessary nursing care and suctioning was provided. Neonates were monitored every 4 hours for improvement in respiratory distress, and Downes' score was calculated. Reduction in Downes' score was used to wean neonates from CPAP, while an increase was considered as an indication of need for mechanical ventilation.

Statistical Analysis
The statistical analysis involved a thorough analysis of the data, utilizing various measures to highlight the key characteristics of the study cohort. Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Science (SPSS) Software version 29 (sample size= $4pq/ L^2$). Categorical variables were expressed as number of patients and percentages, compared using Pearson's Chi - Square test, Student T - test and Anova test. An alpha level of 5% ($p < 0.05$) was considered as statistically significant.

3. Results

The study population consisted of 150 neonates, with a higher proportion of males (88, 58.7%) compared to females (62, 41.3%). The survival rates were comparable between males and females. Among females, 80.6% (n=50) survived without mechanical ventilation, while 19.4% (n=12) required invasive respiratory support. Similarly, among males, 81.8% (n=72) survived, and 18.2% (n=16) required mechanical ventilation. The overall survival rate was 81.3%, with mechanical ventilation required in 18.7% of cases.

The p - value came out to be 0.957, which confirms that there is no significant association between gender and survival or mechanical ventilation rates. (Table 1)

Table 1: Gender distribution and neonatal outcome.

Gender	Survived (N=150)	Mechanical Ventilation (N=150)	Total (N=150)	P - Value
Female	50 (80.6%)	12 (19.4%)	62 (100%)	0.957
Male	72 (81.8%)	16 (18.2%)	88 (100%)	
Total	122 (81.3%)	28 (18.7%)	150 (100%)	

The distribution of gestational age at delivery in the study population (n=150) indicates that the majority of neonates (81, 54.0%) were born between 32 - 36 weeks of gestation, classifying them as late preterm. The survival rates varied significantly with gestational age. Among neonates born at <28 weeks, only 33.3% survived, with a majority (66.7%) requiring mechanical ventilation. Similarly, in the 28–32 weeks group, survival was 57.5%, with 42.5% requiring invasive respiratory support. In contrast, neonates born between 32–36 weeks demonstrated markedly improved outcomes, with 93.8% surviving and only 6.2% requiring mechanical ventilation. Notably, all neonates born at ≥37 weeks survived without the need for mechanical ventilation (100.0%).

The chi - square test confirmed a highly significant p - value (<0.001), indicating that lower gestational age was strongly correlated with increased mechanical ventilation requirements. (Table 2)

Table 2: Gestational Age and neonatal outcome.

Gestational Age (in weeks)	Survived (N=150)	Mechanical Ventilation (N=150)	Total (N=150)	P - Value
<28 Weeks	3	6	9	<0.001
28 - 32 Weeks	23	17	40	<0.001
32 - 36 Weeks	76	5	81	<0.001
37 Weeks and Above	20	0	20	<0.001
Total	122	28	150	<0.001

The study population (n=150) exhibited a high rate of lower - segment caesarean section (LSCS) deliveries, accounting for 58.7% (88 neonates), while spontaneous vaginal delivery (labour naturale) was observed in 33.3% (50 neonates). Among the 150 neonates analysed, survival rates were slightly higher in assisted vaginal deliveries (91.7%) and spontaneous vaginal deliveries (86.0%) compared to those born via lower segment caesarean section (LSCS) (77.0%). Conversely, the proportion of neonates requiring mechanical ventilation was highest in the LSCS group (23.0%), followed by spontaneous vaginal delivery (14.0%), and was lowest in assisted vaginal delivery (8.3%). Despite these variations, the observed differences were not statistically significant (p=0.198). Given these findings, the mode of delivery should be carefully selected based on obstetric indications rather than concerns about neonatal respiratory outcomes alone. (Table 3)

Table 3: Mode of Delivery and neonatal outcome

Mode of Delivery	Survived (N=150)	Mechanical Ventilation (N=150)	Total (N=150)	P - Value
Labour Naturale	43 (86%)	7 (14%)	50 (100%)	0.198
Assisted Vaginal	11 (91.7%)	1 (8.3%)	12 (100%)	0.198
Delivery LSCS	68 (77.0%)	20 (23.0%)	88 (100%)	0.198
Total	122 (80%)	28 (20%)	150 (100%)	0.198

Among the 150 neonates, those who survived had a significantly higher mean birth weight (2.00 ± 0.64 kg) compared to those who required mechanical ventilation (1.26 ± 0.41 kg). The lower birth weight in ventilated neonates suggests a higher vulnerability to respiratory distress, likely due to immature lung development, reduced surfactant production, and an increased risk of complications such as respiratory distress syndrome (RDS) and apnoea. Since the p - value is <0.001, this indicates a highly significant difference in birth weight between the Survived and Mechanical Ventilation groups. Lower birth weight is strongly associated with a higher need for mechanical ventilation.

This strong correlation emphasizes the critical role of birth weight in determining neonatal respiratory outcomes. Low birth weight infants, especially those <1.5 kg, may benefit from early respiratory support strategies, including antenatal corticosteroid administration, non - invasive ventilation, and surfactant therapy. Additionally, close monitoring and targeted interventions in the neonatal intensive care unit (NICU) may help improve survival rates and reduce ventilator dependence in this high - risk group. (Table 4)

Table 4: Birth weight and neonatal outcome.

Birth Weight	Outcome (N=150)	Mean	Std. Deviation	P - Value
Survived	122	2	0.64	<0.001
Mechanical Ventilation	28	1.26	0.41	<0.001

The most common neonatal diagnosis in the study population (n=150) was respiratory distress syndrome (RDS), affecting 70.0% (105 neonates), indicating a high burden of surfactant deficiency, particularly in preterm infants. Among the 150 neonates, those diagnosed with respiratory distress syndrome (RDS) had the highest requirement for mechanical ventilation (24.8%), reflecting the severe respiratory compromise associated with surfactant deficiency and immature lung function. In contrast, neonates with birth asphyxia (4.2%) and meconium aspiration syndrome (4.0%) had significantly lower ventilation rates, suggesting better spontaneous recovery or responsiveness to non - invasive support measures. All neonates with congenital pneumonia survived without requiring ventilation, likely due to early recognition and antibiotic therapy.

The findings underscore the importance of early respiratory support in RDS, particularly in preterm neonates, through interventions such as antenatal corticosteroids, early CPAP, and surfactant administration.

Given the high mechanical ventilation requirement in RDS cases, a targeted respiratory management protocol, including the use of high - flow nasal cannula (HFNC) or non - invasive ventilation (NIV) before intubation, may help reduce ventilation - associated complications and improve survival rates. (Table 5)

Table 5: Diagnosis and the neonatal outcome

Diagnosis	Survived (N=150)	Mechanical Ventilation (N=150)	Total (N=150)	P - Value
Respiratory Distress Syndrome	79 (75.2%)	26 (24.8%)	105 (100%)	0.001
Birth Asphyxia	23 (95.8%)	1 (4.2%)	24 (100%)	0.001
Meconium Aspiration Syndrome	17 (96.0%)	1 (4.0%)	18 (100%)	0.001
Congenital Pneumonia	3 (100.0%)	0 (0.0%)	3 (100%)	0.001
Total	122 (82.0%)	28 (18.0%)	150 (100%)	0.001

The Downes Score, a clinical tool used for assessing respiratory distress, incorporates tachypnea, retractions, cyanosis, and air entry (Figure 2). A score ≥6 is generally indicative of severe respiratory distress, necessitating early CPAP or mechanical ventilation. In this study, among 150 neonates, 45 (30%) had a score of 4, indicating mild to moderate respiratory compromise. The majority of neonates, 76 (50.7%), had a score of 5, reflecting moderate respiratory distress that likely required supportive measures such as oxygen supplementation or non - invasive ventilation. Among the 150 neonates, those who survived had a mean Downes Score of 4.67 (±0.56), whereas those requiring mechanical ventilation had a significantly higher mean score of 5.89 (±0.31). This highlights that higher Downes Scores are strongly associated with worsening respiratory distress, leading to increased ventilatory support requirements.

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The findings suggest that neonates with moderate respiratory distress (score ~5) might benefit from aggressive non - invasive respiratory support, such as early CPAP or high - flow nasal cannula (HFNC), to potentially prevent intubation. (Table 6)

Table 6: Downes score and neonatal outcome.

Downes Score	Outcome (N=150)	Mean	Std. Deviation	P – Value
Survived	122	4.67	0.56	<0.001
Mechanical Ventilation	28	5.89	0.31	<0.001

The duration of continuous positive airway pressure (CPAP) therapy in the study population (n=150) varied significantly, with the majority of neonates (98, 65.3%) requiring CPAP for more than 24 hours, indicating the severity and persistence of respiratory distress. A smaller proportion (35, 23.3%) required CPAP for 12 - 24 hours, while only 11 neonates (7.3%) received CPAP for 6 - 12 hours, and 6 neonates (4.0%) needed CPAP for less than 6 hours. Among the 150 neonates, those receiving CPAP for >24 hours had the highest rate of mechanical ventilation (23.9%), whereas those on CPAP for 12 - 24 hours had the lowest (5.3%), suggesting that effective early CPAP support within the first 24 hours may help reduce the need for invasive ventilation. Since the given p - value is 0.012 (which is <0.05), this suggests a statistically significant association between the duration of CPAP and neonatal outcome (survival or mechanical ventilation). Longer CPAP durations appear to be linked to a higher likelihood of requiring mechanical ventilation.

Shorter CPAP durations (<12 hours) were associated with lower overall mechanical ventilation rates, but this might reflect less severe respiratory distress in those neonates. Conversely, neonates requiring prolonged CPAP (>24 hours) had significantly higher ventilation rates, indicating either treatment failure or severe underlying lung pathology.

These findings suggest that early and optimized CPAP use, particularly within the first 12 - 24 hours, may be crucial in preventing mechanical ventilation. Prolonged CPAP use without improvement may indicate disease progression (e. g., severe RDS, pneumonia), necessitating early escalation to mechanical ventilation. (Table 7)

Table 7: Duration of CPAP and neonatal outcome

Duration of CPAP	Survived	Mechanical	Total (N=150)	P - Value
<12 Hrs	14 (82.8%)	Ventilation 3 (18.2%)	14 (100%)	0.012
12 - 24 Hrs	33 (94.7%)	2 (5.3%)	35 (100%)	
>24 Hrs	75 (76.1%)	23 (23.9%)	98 (100%)	
Total	122 (81.3%)	27 (18.7%)	150 (100%)	

The incidence of complications in the study population (n=150) was low, with 146 neonates (97.3%) experiencing no complications, while only 4 cases (2.7%) developed pneumothorax. The low rate of complications suggests effective neonatal respiratory management and highlights the safety of the applied ventilator strategies. Among the 150 neonates, 146 (97.3%) had no complications, with an 83.8% survival rate and only 16.2% requiring mechanical ventilation. In contrast, neonates (2.7%) developed pneumothorax, of whom a significantly higher proportion (66.7%) required mechanical ventilation, with only 33.3% surviving without invasive respiratory support.

Since the given p - value is 0.011, this indicates a statistically significant association between complications (like pneumothorax) and neonatal outcome. Infants with pneumothorax had a higher likelihood of requiring mechanical ventilation compared to those without complications.

These findings emphasize that pneumothorax is a critical complication in neonates requiring CPAP or ventilator support, significantly increasing morbidity and the need for invasive respiratory management. This underscores the importance of close monitoring, early recognition, and preventive strategies such as optimal CPAP settings and lung - protective ventilation to reduce the risk of barotrauma and improve neonatal outcomes. (Table 8)

Table 8: Complications and neonatal outcomes

Complication	Survived	Mechanical	Total (N=150)	P - Value
No Complication	121 (83.8%)	Ventilation 25 (16.2%)	146 (100%)	0.011
Complication	1 (25%)	3 (75%)	4 (100%)	
(Pneumothorax) Total	122 (81.3%)	28 (18.7%)	150 (100%)	

In this study population (n=150), 122 neonates (81.3%) survived without requiring mechanical ventilation, while 28 neonates (18.7%) required mechanical ventilation, indicating a substantial proportion requiring advanced respiratory support. The survival rate is promising, reflecting the efficacy of non - invasive respiratory support strategies such as CPAP and antenatal steroid administration. The chi - square test yielded a highly significant p - value (**p < 0.0001**), suggesting that most neonates responded well to initial respiratory management, while a smaller group exhibited greater respiratory compromise necessitating invasive support. These findings emphasize the need for continuous monitoring and early intervention to prevent progression to severe respiratory distress.
(Table 9)

Table 9: Neonatal outcomes based on intervention

Outcome	Frequency (N=150)	Percentage (%)
Survived	122	81.3
Mechanical Ventilation	28	18.7
Total	150	100

One third (30.0%) of neonates had a short NICU stay, meaning they were stable.38% had a moderate NICU stay, requiring extended respiratory support but avoiding mechanical ventilation, 32.0 % had a prolonged NICU stay (>10 days) primarily due to severe respiratory distress or prematurity. (Table 10)

Table 10: Duration of neonatal stay in NICU.

Duration	Frequency (N=150)	Percentage (%)
Short Stay (<= 5 Days)	45	30
Moderate Stay (6 - 10 Days)	57	38
Prolonged Stay (>10 Days)	48	32
Total	150	100

Since the given p - value is <0.001, this indicates a highly significant association between CPAP duration and hospital stay duration. Longer CPAP durations (especially >24 hours) were associated with prolonged hospital stays, while shorter durations were linked to shorter stays. Short CPAP duration (<6 hrs) mostly short NICU stay.83.3% of neonates needing CPAP for <6 hrs were discharged in less than equal to 5 days. None required prolonged NICU stay. Moderate CPAP duration (6 - 12hrs) = mostly moderate NICU stay.6 - 12 hrs - 54.5 % had moderate NICU stays.12 - 24 hrs 51.4 % had moderate NICU stays, while 13.3% needed prolonged care. Prolonged CPAP duration (>24 hrs) is strong predictor of NICU stay.42.9% of neonates on CPAP >24 hrs had prolonged NICU stays. Only 24.5 % of these cases were discharged in less than 5 days. (Table 11)

Table 11: NICU stay vs duration of CPAP.

Duration of CPAP	Short Stay	Moderate Stay	Prolonged Stay	Total	P Value
<6 Hrs	5	1	0	6	<0.001
6 - 12 Hrs	4	6	1	11	
12 - 24 Hrs	12	18	5	35	
>24 Hrs	24	32	42	98	
Total	45	57	48	150	

4. Discussion

The present study observed a male predominance among neonates with respiratory distress managed on bubble CPAP, with 88 (58.7%) being males and 62 (41.3%) being females. Kachare et al. and Byram et al. [14, 15] reported a similar trend, with male neonates comprising 64.2% & 61.5% of the study population requiring CPAP support, reinforcing the concept of male vulnerability in neonatal morbidity.

In our study, a majority of neonates (54.0%) were born between 32 - 36 weeks of gestation, followed by 26.7% between 28 - 32 weeks, 6.0% before 28 weeks, and only 13.3% at term (≥37 weeks). This high prevalence of late and moderate preterm neonates correlates with increased susceptibility to respiratory distress and the necessity for CPAP intervention. Kachare et al. and Manandhar et al. [14, 16] reported a mean gestational age of 34.64±6.6 weeks and 36.67±3.4 weeks respectively, with 58.3% of neonates born between 32 - 36 weeks and 47.5% of neonates being late preterm, closely paralleling our findings.

Thukral et al. [18] reported a similar distribution, where 67.1% of neonates requiring CPAP were moderate to late preterm, with a lesser contribution from term neonates.

The most common diagnosis in our study population was respiratory distress syndrome (RDS), affecting 70.0% (105 neonates), followed by birth asphyxia (16.0%, 24 neonates), meconium aspiration syndrome (MAS) (12.0%, 18 neonates), and congenital pneumonia (2.0%, 3 neonates). Our findings align with those of Kachare et al. [14], who reported RDS in 71.33% of neonates managed on bubble CPAP. Parasuramappa HSC et al. [17] found RDS in 91% of preterm neonates between 28 - 36 weeks, indicating a higher proportion of severe cases in their cohort. Thukral et al. [18] reported that CPAP reduced the need for mechanical ventilation by 66%, correlating with our observation that most neonates responded well to non - invasive ventilation.

The Downes Score at admission showed that 50.7% of neonates had a score of 5, followed by 30% with a score of 4, and 19.3% with a score of 6. This suggests that most neonates had moderate to severe respiratory distress upon presentation. Buch et al. [21] found that a Downes Score >6 at 15 - 20 minutes post - CPAP initiation was a predictor of failure, reinforcing our observation that neonates with a score of 6 required prolonged CPAP or escalation to mechanical ventilation. Kachare et al. [14] emphasized that persistent distress despite bubble CPAP correlated with higher Downes Scores, aligning with our findings. Gupta et al. [19] noted that early CPAP application in neonates with Downes Scores 4 - 6 significantly reduced ventilation requirements, supporting our evidence that moderate distress cases responded well to CPAP.

The majority (65.3%, 98 neonates) required CPAP for more than 24 hours, while 23.3% (35 neonates) needed 12 - 24 hours, 7.3% (11 neonates) required 6 - 12 hours, and only 4.0% (6 neonates) needed <6 hours. This pattern suggests that prolonged CPAP support is often required for neonatal respiratory distress. Gupta et al. [19] also reported that early CPAP intervention led to shorter NICU stays, reinforcing the need for timely initiation. Buch et al. [21] reported higher failure rates in neonates needing prolonged CPAP, similar to our neonates requiring >24 hours of support. Parasuramappa HSC et al. [17] noted that CPAP use beyond 48 hours was associated with improved lung recruitment, supporting our finding of a majority requiring prolonged CPAP (>24 hours).

The complication rate in our study was low, with only 2.7% of neonates developing pneumothorax and 97.3% experiencing no complications. This outcome aligns with the findings of Kachare et al. [14], where pneumothorax occurred in 3.1% of neonates, confirming that Bubble CPAP is a safe mode of non - invasive ventilation

Parasuramappa et al. [17] reported a 2.4% incidence of pneumothorax, nearly identical to our findings, emphasizing that careful CPAP pressure titration is essential to avoid barotrauma.

In our study, 81.3% of neonates survived on CPAP, while 18.7% required mechanical ventilation ($p < 0.0001$). Manandhar et al. [16] found that 61% of neonates improved on CPAP, while 39% required invasive ventilation, demonstrating a significantly lower success rate than our study, likely due to differences in gestational age distribution. Gupta et al. [19] reported that early CPAP initiation reduced ventilation needs to 16.5%, aligning closely with our findings.

In our study, 30% of neonates had a short NICU stay (≤5 days), 38% had a moderate stay (6–10 days), and 32% had a prolonged stay (>10 days). Kachare et al. [14] reported an average NICU stay of 9.6 ± 2.3 days, aligning closely with our moderate - stay group. Manandhar et al. [16] reported a mean NICU duration of 95.7 ± 3 hours (4 days), lower than in our study, likely due to differences in patient selection.

Parasuramappa et al. [17] reported that neonates with successful CPAP weaning had an average stay of 7.2 days, closely matching our moderate - stay cohort. Jeya Balaji et al. [20] documented a prolonged NICU stay (>10 days) in 28% of neonates, similar to our study.

Gestational age significantly influenced respiratory outcomes ($p < 0.001$) in our study. Among neonates <28 weeks, 66.7% required ventilation, whereas 100% of neonates ≥37 weeks survived without mechanical ventilation. Gupta et al. [19] reported that neonates <30 weeks had a 35% mechanical ventilation rate, closely aligning with our results.

Jeya Balaji et al. [20] reported that neonates ≥32 weeks had 93% survival, aligning with our 93.8% survival rate in 32–36 weeks gestation.

Among the 150 neonates, the mean birth weight of those who survived on Bubble CPAP was 2.00 ± 0.64 kg, whereas neonates who required mechanical ventilation had a significantly lower mean birth weight of 1.26 ± 0.41 kg ($p < 0.001$). Our findings are comparable to Kachare et al. [14], who reported a mean birth weight of 1.937 ± 1.34 kg, with 71.33% of neonates successfully weaned off Bubble CPAP, while 28.67% required mechanical ventilation, reinforcing the association between lower birth weight and CPAP failure. Our study also aligns with Thukral et al. [18], who noted that neonates with birth weight <1.5 kg had a 66% higher requirement for mechanical ventilation, further emphasizing that lower birth weight contributes to poor CPAP outcomes.

The present study revealed that among neonates diagnosed with respiratory distress syndrome (RDS), 75.2% survived on CPAP, while 24.8% required mechanical ventilation ($p=0.001$). For birth asphyxia cases, 95.8% neonates survived on CPAP, with only 4.2% requiring invasive ventilation. Similarly, in meconium aspiration syndrome (MAS), 96% survived on CPAP, and 4% required mechanical ventilation. The lowest ventilation requirement was observed in congenital pneumonia, where all neonates (100%) survived on CPAP.

Comparing with Kachare et al. [14], who reported that neonates with RDS had the highest CPAP failure rate (31.2%), our study demonstrates a slightly lower ventilation requirement, possibly due to early intervention strategies. Gupta et al. and Jeya Balaji et al. [19, 20] both highlighted the higher CPAP success rate in non - RDS cases compared to RDS, which is consistent with our results.

In our study, neonates with a mean Downes Score of 4.67 ± 0.56 had an 81.3% survival rate, while those with a mean score of 5.89 ± 0.31 had an 18.7% requirement for mechanical ventilation ($p < 0.001$).

Kachare et al. [14] reported a mean Downes Score of 5.1 ± 0.8 in successfully managed neonates and 6.2 ± 0.7 in those requiring ventilation, mirroring our findings. Manandhar et al. [16] found that a Downes Score >5 predicted CPAP failure in 29% of cases, similar to our study. Byram et al. [15] showed that neonates with a Downes Score >6 had a 43% failure rate on CPAP, reinforcing the predictive value of Downes Scoring. Gupta et al. and Jeya Balaji et al. [19, 20] further support the role of Downes Score in guiding CPAP failure prediction, with comparable ventilation rates in neonates scoring above 5 - 6.

In our study, neonates requiring CPAP >24 hours had the highest ventilation requirement (23.9%), whereas those requiring CPAP for 12 - 24 hours had the lowest ventilation requirement (5.3%). Comparative studies such as Kachare et al. [14] reported CPAP duration >24 hours in 60% of neonates, with a higher failure rate in prolonged CPAP cases, aligning with our findings. Manandhar et al. [16] observed that neonates requiring CPAP for >48 hours had a significantly higher mechanical ventilation rate (42%), reinforcing the threshold of CPAP failure beyond 24 hours.

In our study, 97.3% of neonates had no complications, with a survival rate of 83.8% and a ventilation requirement of 16.2%. However, among the 2.7% neonates who developed pneumothorax, 75% required mechanical ventilation, highlighting the severity of this complication. Byram et al. [15] found that pneumothorax increased CPAP failure by 62%, reinforcing the severe impact of barotrauma. Jeya Balaji et al. [20] also confirmed that CPAP settings need to be carefully adjusted to prevent pneumothorax and improve outcomes.

In our study, neonates with a Downes Score of 4 had the shortest NICU stay, with 88.9% discharged within 5 days, while those with a score of 6 had a 93.1% prolonged NICU stay (>10 days, $p < 0.001$). Parasuramappa et al. and Thukral et al. [17, 18] all showed that higher Downes Scores correlated with longer NICU stays, reinforcing our conclusions. Gupta et al. and Jeya Balaji et al. [19, 20] similarly demonstrated that early assessment with Downes Score accurately predicts NICU duration and respiratory outcomes.

In our study, preterm neonates (<28 weeks) had the highest prolonged NICU stay (44.4%), whereas term neonates (≥37 weeks) had the shortest NICU stay, with 75% discharged within 5 days ($p < 0.001$). Comparing with Kachare et al. [14], preterm neonates had a 50% prolonged NICU stay, closely matching our 44.4% finding. Manandhar et al. [16] reported that neonates <32 weeks had an 85% NICU stay >10 days, aligning with our findings. Byram et al. [15], Parasuramappa et al. and Thukral et al. [17, 18] all confirmed that gestational age strongly predicts NICU stay, similar to our study. Gupta et al. and Jeya Balaji et al. [19, 20] also reported that neonates <32 weeks had significantly longer NICU stays.

In our study, CPAP duration >24 hours was associated with a 42.9% prolonged NICU stay, while CPAP <6 hours had the shortest NICU stay, with 83.3% discharged within 5 days ($p < 0.001$).

Comparing with Kachare et al. [14], prolonged CPAP (>24 hours) correlated with longer NICU stays in 45% of cases, similar to our 42.9% finding. Byram et al., Manandhar et al., and Parasuramappa et al. all found that longer CPAP duration increased NICU stay, consistent with our results. [15 - 17]

5. Conclusions

This study highlights the strong correlation between gestational age, birth weight, respiratory distress severity, and neonatal outcomes. Timely antenatal steroid administration, early CPAP initiation, and individualized respiratory management remain critical strategies in improving neonatal survival and reducing morbidity. Future research should focus on optimizing respiratory support strategies to minimize mechanical ventilation dependency and improve long - term neonatal outcomes.

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