Section: Neonatology

Original Research Article

COMPARISON OF CLINICAL OUTCOMES OF BUBBLE CPAP AND NIPPV IN NEONATES WITH RESPIRATORY DISTRESS SYNDROME

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Received *: 16/11/2025*
Received in revised form *: 05/01/2026*
Accepted *: 23/01/2026*

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DOI: 10.70034/ijmedph.2026.1.140

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (1); 778-783

ABSTRACT

Background: Respiratory distress syndrome (RDS) remains a leading cause of morbidity and mortality among preterm neonates. Non-invasive ventilation strategies such as bubble continuous positive airway pressure (bubble CPAP) and nasal intermittent positive pressure ventilation (NIPPV) are widely used as primary respiratory support; however, comparative evidence on short-term outcomes remains limited. This study aimed to compare the clinical outcomes of neonates with RDS managed with bubble CPAP and NIPPV.

Materials and Methods: This prospective observational study was conducted in the NICU of a tertiary care teaching hospital over an 18-month period. A total of 120 preterm neonates with RDS requiring non-invasive ventilation at birth were enrolled, of whom 60 received bubble CPAP and 60 received NIPPV. Baseline demographic, birth, and antenatal characteristics were recorded. Outcomes assessed included surfactant requirement, need for mechanical ventilation, duration of oxygen therapy, length of hospital stay, and survival to discharge. Data were analyzed using descriptive and comparative statistics.

Results: Baseline demographic, birth, and antenatal characteristics were comparable between the two groups. Surfactant use and requirement for mechanical ventilation did not differ significantly between bubble CPAP and NIPPV. Neonates managed with NIPPV had a significantly shorter duration of oxygen requirement and hospital stay compared to those on bubble CPAP. Survival to discharge was significantly higher, and mortality was lower, in the NIPPV group.

Conclusion: Both bubble CPAP and NIPPV were effective non-invasive ventilation modalities in the management of neonatal RDS; however, NIPPV was associated with improved short-term outcomes, including reduced oxygen dependency, shorter hospital stay, and higher survival to discharge.

Keywords: Respiratory distress syndrome; Preterm neonates; Bubble CPAP; Nasal intermittent positive pressure ventilation; Non-invasive ventilation.

INTRODUCTION

Neonatal respiratory distress syndrome (RDS) remains a dominant cause of early respiratory morbidity in preterm infants, primarily driven by pulmonary surfactant deficiency and structural lung immaturity, with risk and severity increasing as gestational age decreases.[1] Contemporary evidence-based care pathways emphasize lung-protective strategies from birth, including early non-invasive respiratory support, judicious oxygen use, timely surfactant therapy, and minimizing exposure to invasive mechanical ventilation whenever feasible.[1] Nasal continuous positive airway pressure (nCPAP) is widely accepted as a first-line non-invasive modality in preterm infants with or at risk of RDS, and early use is associated with reduced need for invasive ventilatory support.[2] Bubble CPAP (B-

CPAP) is a commonly used CPAP-generating system and is attractive in resource-constrained settings because of its relative simplicity and lower cost; clinical trials comparing B-CPAP with ventilator-derived CPAP suggest that bubble systems can provide effective respiratory support and may reduce hospital stay and cost in preterm infants with respiratory distress.[3]

Despite the central role of CPAP, CPAP failure—manifesting as worsening respiratory distress, rising oxygen requirement, apnea, or hypercapnia—continues to occur in a clinically meaningful subset of preterm neonates. Nasal intermittent positive pressure ventilation (NIPPV) has therefore been adopted in many units as either primary support or escalation therapy. A recent Cochrane review evaluating early NIPPV versus early nCPAP in preterm infants reported that early NIPPV likely reduces respiratory failure and the need for endotracheal intubation during the first week of life compared with early nCPAP, while effects on mortality were minimal or uncertain.[2] However, evidence is not uniform across risk strata; in extremely low birthweight infants, comparative analyses have reported similar primary noninvasive ventilation failure rates between NIPPV and nCPAP.[4] In addition, practice variation persists regarding synchronization, ventilator settings, and patient selection—factors that may influence effectiveness and tolerance.

Data from India and similar settings are especially relevant because non-invasive ventilation is frequently implemented under constraints related to equipment availability, staffing, and case-mix. A randomized trial from an Indian tertiary center reported improved short-term efficacy of nonsynchronized NIPPV compared with CPAP in preventing early intubation among neonates with respiratory distress, highlighting potential benefits in real-world practice.[5] Furthermore, evidence syntheses in neonatal RDS suggest that, in specific contexts such as post-extubation support, noninvasive strategies including NIPPV may reduce the risk of reintubation compared with nCPAP, although certainty depends on study quality and heterogeneity.[6] Given the ongoing uncertainty and variability in outcomes across populations and clinical scenarios, generating locally applicable comparative effectiveness data is important.

Therefore, this hospital-based observational study was undertaken to compare clinical outcomes among preterm neonates with RDS managed initially with NIPPV versus Bubble CPAP in a tertiary NICU setting.

MATERIALS AND METHODS

Study design and setting: This hospital-based prospective observational study was conducted in the NICU of a tertiary care teaching hospital in Ahmedabad. The study was initiated after approval from the Institutional Review Board, and all procedures were carried out in accordance with ethical standards, ensuring confidentiality of patient data. The study was undertaken exclusively for academic and publication purposes.

The total study duration was 18 months, from 3 August 2023 to 2 February 2025. The initial 6 months (3 August 2023 to 2 February 2024) were devoted to protocol development, methodological refinement, and preparatory analytical work. This was followed by 12 months of prospective data collection and outcome analysis from 3 February 2024 to 2 February 2025.

Study population and sample size: The study population comprised preterm neonates (extreme, very, and moderate-to-late preterm) admitted to the NICU with a diagnosis of respiratory distress syndrome (RDS) who required non-invasive respiratory support at birth. A duration-based sample size of 120 neonates was included. During the study period, all eligible neonates were directly initiated on either bubble CPAP (B-CPAP) or nasal intermittent positive pressure ventilation (NIPPV) as primary respiratory support. Of these, 60 neonates were managed with B-CPAP and 60 with NIPPV. Written informed consent was obtained from either parent or legal guardian in their local language prior to enrollment.

Inclusion and exclusion criteria

Inclusion criteria were neonates admitted to the NICU with RDS who required non-invasive ventilation in the form of B-CPAP or NIPPV immediately after birth. Exclusion criteria included neonates with gross congenital anomalies, neonates whose parents declined consent, and neonates requiring invasive mechanical ventilation at birth.

Allocation and baseline assessment: All neonates fulfilling inclusion criteria were enrolled consecutively. The choice of non-invasive ventilation modality was based on unit protocols and availability of equipment. In situations where there was an imbalance in the number of neonates initiated on either modality, an equal number of patients were randomly selected to ensure comparable group sizes.

At admission, detailed baseline data were recorded, including gestational age, sex, birth weight, and categorization into extremely low birth weight, very low birth weight, or low birth weight groups. Additional perinatal variables included mode of delivery, APGAR scores at 1 and 5 minutes, age at admission, and severity of respiratory distress assessed using the Silverman–Anderson score.

Antenatal and maternal variables: A comprehensive antenatal and maternal history was obtained for each neonate. Information regarding antenatal corticosteroid administration, including number of doses and interval between last dose and delivery, was documented. Maternal comorbidities and obstetric risk factors such as pregnancy-induced hypertension, gestational diabetes mellitus, thyroid disorders, pre-eclampsia, oligohydramnios, polyhydramnios, premature rupture of membranes,

chorioamnionitis, and antepartum hemorrhage were systematically recorded.

Respiratory management protocol: Neonates with mild, moderate, or severe RDS, as determined by the Silverman–Anderson score, received non-invasive respiratory support using either B-CPAP or NIPPV. For B-CPAP, pressure settings ranged from 5 to 10 cmH_2O, while NIPPV was delivered as non-synchronized NIPPV with PEEP of 5–10 cmH_2O and PIP of 10–25 cmH_2O, at the discretion of the treating clinician.

Once clinical stabilization was achieved at minimal pressure settings (5 cmH_2O for B-CPAP or 5/10 cmH_2O for NIPPV), neonates were gradually weaned to supplemental oxygen via nasal cannula and subsequently to room air, according to NICU protocols and clinical status.

Surfactant therapy and escalation of support: Surfactant therapy was administered using the INSURE technique when neonates required a mean airway pressure of 8 cmH_2O with an FiO_2 of 0.3. Curosurf was administered at an initial dose of 200 mg/kg within the first hour of life. In extremely preterm neonates (<28 weeks gestation), surfactant was administered prophylactically within the first hour. If FiO_2 requirements exceeded 0.4, repeat doses of 100 mg/kg were administered at intervals of 6–12 hours, with a maximum of three doses.

Failure of non-invasive ventilation was defined by persistent FiO_2 requirement >0.6, worsening work of breathing, recurrent apnea, hypercarbia, or a Silverman–Anderson score >7 despite maximal support. These neonates were intubated and mechanically ventilated. Criteria for extubation included a mean airway pressure <8 cmH_2O and FiO_2 <0.3.

Supportive care and monitoring: Enteral feeding with expressed breast milk was initiated via orogastric tube while neonates were on positive pressure ventilation, with intermittent venting for gastric decompression. Continuous monitoring of vital signs was performed. Silverman–Anderson scores and FiO_2 were recorded hourly for the first six hours, followed by six-hourly assessments.

Outcome measures: Primary safety outcomes included clinically significant pneumothorax, septal necrosis, and abdominal distension. Pneumothorax was confirmed radiologically when clinically suspected. Septal integrity and abdominal circumference were assessed six-hourly, with abdominal distension defined as an increase of more than 2 cm from baseline. Secondary outcomes included duration of oxygen requirement, duration of non-invasive ventilation, total hospital stay, and need for mechanical ventilation. Additional neonatal morbidities such as intraventricular hemorrhage, necrotizing enterocolitis, bronchopulmonary dysplasia, retinopathy of prematurity, and sepsis were assessed according to standard unit protocols during hospital stay.

Equipment used: Both B-CPAP and NIPPV were delivered using centralized compressed air and oxygen systems with an SLE NEO2 BLEND air–oxygen blender, FP 850 heated humidifier, compatible dual heated respiratory circuits, and Fisher and Paykel nasal interfaces. For B-CPAP, a dedicated bubble CPAP generator valve was incorporated into the expiratory limb, and interface adjustments were made to ensure optimal pressure delivery.

Statistical analysis: Data were entered into a structured proforma and analyzed using descriptive statistics. Categorical variables were expressed as proportions, and continuous variables as mean with standard deviation. Comparative analyses were performed, and statistical significance was assessed where applicable.

RESULTS

A total of 120 neonates with respiratory distress syndrome were included and managed either with bubble CPAP or NIPPV. The demographic characteristics of the study population are summarized in [Table 1]. The majority of neonates in both groups belonged to the gestational age category of 32–36 weeks and 6 days, with a smaller proportion of extremely preterm infants. The sex distribution was comparable between the two groups, with a slight male predominance overall. Most neonates had a birth weight between 1500 and 2499 grams, and the mean birth weight was similar across both modalities, indicating baseline comparability with respect to maturity and growth parameters.

The birth-related characteristics are detailed in [Table 2]. Caesarean section was the more frequent mode of delivery in both groups. Mean APGAR scores at one and five minutes were comparable, suggesting similar immediate postnatal adaptation. The majority of neonates in both groups had a Silverman–Anderson score in the moderate range at admission, while a smaller proportion presented with severe respiratory distress. Most neonates were admitted within the first hour of life, reflecting early identification and initiation of respiratory support.

Antenatal factors and maternal comorbidities are presented in [Table 3]. Antenatal corticosteroids were not administered in a substantial proportion of mothers in both groups, while among those who received steroids, the mean number of doses and the interval between the last dose and delivery were comparable, with no statistically significant difference between groups. Maternal conditions such as pregnancy-induced hypertension, pre-eclampsia, premature rupture of membranes, oligohydramnios, and chorioamnionitis were observed across both groups without marked imbalance, indicating similar antenatal risk profiles.

The requirement for surfactant therapy and mechanical ventilation is shown in [Table 4]. A majority of neonates in both groups did not require surfactant administration, and among those who did, most received a single dose. The distribution of

surfactant use did not differ significantly between the two groups. Similarly, most neonates did not require invasive mechanical ventilation, and when required, the duration was predominantly short, with no statistically significant difference between bubble CPAP and NIPPV groups.

Among discharged neonates, the duration of oxygen requirement and length of hospital stay are compared in [Table 5]. A significantly higher proportion of neonates in the NIPPV group required oxygen for a shorter duration compared to those on bubble CPAP. Likewise, the total duration of hospital stay was significantly shorter in the NIPPV group, whereas prolonged hospitalization beyond 14 days was more frequently observed in the bubble CPAP group, indicating better clinical recovery with NIPPV.

The final outcomes in terms of discharge and mortality are depicted in [Table 6]. Overall survival was high in both groups; however, the proportion of successfully discharged neonates was significantly higher in the NIPPV group. Mortality was lower among neonates managed with NIPPV compared to bubble CPAP, and this difference reached statistical significance, suggesting a favorable outcome with NIPPV in the management of neonatal respiratory distress syndrome.

Table 1: Demographic profile between study groups.

		Bubble CPAP No. (%)	NIPPV No. (%)	Total (%)
Gestational age	<28 week	3(2.5%)	11(9.1%)	14(11.6%)
	28- 31week+6days	19(15.8%)	18(15%)	37(30.8%)
	32- 36week+6days	38(31.6%)	31(25.8%)	69(57.5%)
Sex	Male	32(26.6%)	33(27.5%)	65(54.1%)
	Female	28(23.3%)	27(22.5%)	55(45.8%)
Birth weight (In grams)	<1000gms	3(2.5%)	3(2.5%)	6(5%)
	1000-1499gms	8(6.6%)	17(14.1%)	25(20.8%)
	1500-2499gms	49(40.8%)	40(33.3%)	89(74.1%)
	Mean weight(grams)	1816.2	1772.68	

Table 2: Birth profile between study groups

		Bubble CPAP No. (%)	NIPPV No. (%)	Total(%)
Mode of delivery	Per vaginal	28(23.3%)	19(15.8%)	47(39.1%)
	LSCS	32(26.6%)	41(34.1%)	73(60.8%)
APGAR Score Mean (SD)	At 1 minute	7.6(0.7)	7.5(0.72)	-
	At 5 minutes	9.2(0.8)	9.3(0.76)	-
Silverman Anderson score	≤3	11(9.1%)	8(6.6%)	19(15.8%)
	4-6	36(30%)	34(28.3%)	70(58.3%)
	≥7	13(10.8%)	18(15%)	31(25.8%)
Age on admission (In hours of life)	Within 1st HOL	54(45%)	54(45%)	108(90%)
	After 1st HOL	6(5%)	6(5%)	12(10%)

Table 3: Antenatal profile between study groups.

		Bubble CPAP No. (%)	NIPPV No. (%)	Total (%)	
Antenatal corticosteroid (Dexamethasone)	Not given	34(28.3%)	38(31.6%)	72(60%)	
	Total No. of doses given Mean (SD)	2.6(1.19)	2.6(1.32)	48(40%)	
	Duration between last dose and delivery (in Hrs) Mean (SD)	4.8(3.8)	6.23(6.5)	-	t-test:0.908 pvalue:0.370
Maternal history and complications	GDM	2(1.6%)	2(1.6%)	4(3.2%)	
	PIH	5(4.1%)	5(4.1%)	10(8.2%)	
	Hypothyroid	4(3.3%)	4(3.3%)	8(6.6%)	
	Pre-eclampsia	7(5.8%)	5(4.1%)	12(9.9%)	
	APH	4(3.3%)	3(2.5%)	7(5.8%)	
	Oligohydramnios	9(7.5%)	5(4.1%)	14(11.6%)	
	Polyhydramnios	0(0%)	4(3.3%)	4(3.3%)	
	PROM	12(10%)	9(7.5%)	21(17.5%)	
	Chorioamnionitis	7(5.8%)	3(2.5%)	10(8.2%)	

Table 4 Surfactant and mechanical ventilation requirements between study groups.

			Bubble CPAP No. (%)	NIPPV No. (%)	Total (%)	
Surfactant (curosurf)	No. of doses	Not given	38(31.6%)	34(28.3%)	72(60%)	Chi square:0.58 pvalue:0.746
		1	20(16.6%)	24(20%)	44(36.6%)	
		2	2(1.6%)	2(1.6%)	4(3.2%)	
Mechanical ventilation duration (In days)	Not required		45(37.5%)	44(36.6%)	89(74.1%)	Chi square:0.04 pvalue:0.835
	Required (days)	1-5	16(13.3%)	15(12.5%)	31(25.8%)	
		6-10	1(0.8%)	0(0%)	1(0.8%)	

Table 5: Comparison of hospital stay and total duration of oxygen requirements among discharge patients of study groups.

		Bubble CPAP No. (%)	NIPPV No. (%)	Total	
Total duration of oxygen requirement	<7days	30(25%)	45(37.5%)	75(62.5%)	Chi square:8.542 p-value:0.014
	7-14days	24(20	11(9.1%)	35(29.1%)	
	>14days	6(5%)	4(3.3%)	10(8.3%)	
Total days of hospital stay	<7days	14(11.6%)	25(20.8%)	39(32.5%)	Chi square:14.31 p-value:0.0008
	7-14days	18(15%)	26(21.6%)	44(36.6%)	
	>14days	28(23.3%)	9(7.5%)	37(30.8%)	

Table 6 Study of outcome of patients in form of Discharge and Death.

	Bubble CPAP No. (%)	NIPPV No. (%)	Total	
Successfully discharge	50(41.6%)	57(47.5%)	107(89.2%)	Chi square:4.228 p-value:0.04
Death	10(8.3%)	3(2.5%)	13(10.8%)	

DISCUSSION

In this prospective observational cohort of preterm neonates with RDS managed with primary non-invasive respiratory support, NIPPV was associated with shorter oxygen dependency and hospitalization and a higher likelihood of survival to discharge. These findings are biologically plausible because non-invasive strategies that avert or shorten exposure to invasive mechanical ventilation are consistently linked to reduced ventilator-associated lung injury in preterm infants, with potential downstream benefits for respiratory recovery and clinical course.[7] Contemporary syntheses of evidence comparing CPAP and NIPPV emphasize that the incremental ventilatory assistance provided by NIPPV (relative to CPAP) can improve ventilatory stability and reduce early respiratory decompensation in selected populations, although results vary by gestational age, interface, synchronization, and clinical context.[8]

Our observation of improved short-term clinical trajectories with NIPPV aligns with higher-level evidence showing advantages of NIPPV over CPAP in post-extubation settings. A large pragmatic comparative-effectiveness study in very preterm infants (<29 weeks) reported that CPAP was inferior to NIPPV for "mode failure" within 72 hours, although CPAP was noninferior for reintubation outcomes when rescue strategies were available.[9] Similarly, a secondary analysis of a multicenter randomized trial (NASONE) found fewer reintubations and shorter invasive mechanical ventilation duration among infants supported with NIPPV (or NHFOV) compared with NCPAP after extubation, particularly in extremely preterm or more severely ill subgroups.[10] While these studies address post-extubation support rather than primary mode selection at birth, they reinforce the concept that additional noninvasive ventilatory assistance can translate into clinically meaningful reductions in escalation of respiratory support, which may contribute to shorter recovery time.

Not all comparative studies demonstrate clear superiority of NIPPV over CPAP, which underscores the importance of patient selection and protocolized delivery. For example, a retrospective cohort comparing "high CPAP" (≥9 cmH_2O) with NIPPV reported no difference in failure rates, although the high-CPAP group more often required transition to an alternate noninvasive mode.[11] This suggests that in some units, optimization of CPAP (including higher pressures when appropriate) may narrow outcome differences; conversely, variation in delivered pressures, leak, interface fit, and staff experience can influence apparent effectiveness of either modality.

With respect to the bubble CPAP platform, the evidence base indicates that the pressure source itself may affect treatment failure but has less consistent impact on major outcomes. The 2023 Cochrane review comparing bubble CPAP with other CPAP pressure sources concluded that bubble CPAP may reduce CPAP treatment failure but probably has little or no impact on mortality, while increasing the risk of moderate-to-severe nasal injury.[12] These conclusions support interpreting our between-group differences cautiously: while NIPPV appeared to confer advantage in recovery-related outcomes in our setting, differences in device platform, implementation fidelity, and nursing/respiratory therapist expertise could also contribute. This is further supported by implementation science data showing that structured bubble-CPAP programs (training, guidelines, and competency checks) can substantially improve clinically important outcomes, including reduced oxygen exposure and improved survival without BPD in very preterm infants.[13] Therefore, local system factors and the consistency of device application may partly explain observed differences in oxygen requirement and length of stay.

Although our results demonstrated improved survival to discharge with NIPPV, prior syntheses of non-invasive ventilation note that mortality differences between NIPPV and CPAP are not always demonstrable across heterogeneous trials and populations, and outcomes can be driven by baseline risk, co-interventions, and escalation thresholds.[8,14] In our cohort, similar baseline distributions of gestational age, birth weight strata, antenatal corticosteroid exposure, and surfactant/ventilation requirements reduce—but do not eliminate—the possibility of residual confounding inherent to observational designs.

This study has limitations. Treatment allocation was not randomized and depended on unit protocol and equipment availability, which can introduce selection

bias and confounding by indication. NIPPV was non-synchronized, and the extent to which synchronization, pressure settings, and interface type modify outcomes could not be separately evaluated. Outcomes were limited to short-term hospital course and survival to discharge; longer-term morbidities (e.g., BPD severity and neurodevelopment) were not the focus of the present analysis. Despite these limitations, the study provides locally relevant comparative effectiveness data and supports the need for adequately powered randomized trials in similar settings, with standardized protocols for initiation, monitoring, and weaning of both modalities.

CONCLUSION

In this prospective observational study of preterm neonates with respiratory distress syndrome, both bubble CPAP and NIPPV were effective as primary non-invasive ventilatory strategies; however, NIPPV was associated with superior short-term clinical outcomes. Neonates managed with NIPPV demonstrated a significantly shorter duration of oxygen requirement and hospital stay, along with higher survival to discharge and lower mortality compared to those supported with bubble CPAP. Baseline demographic, antenatal, and perinatal characteristics, as well as surfactant use and need for mechanical ventilation, were comparable between groups, suggesting that the observed differences were attributable to the ventilation modality. These findings support the preferential use of NIPPV as an initial non-invasive respiratory support in preterm neonates with respiratory distress syndrome, while emphasizing the need for larger randomized controlled trials to confirm these results and guide standardized practice.

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