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Modality of Respiratory Support in Preterm Neonates with Respiratory Distress and its Outcome

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ABSTRACT

Background: Respiratory distress syndrome (RDS) remains one of the leading causes of morbidity and mortality among preterm neonates. Advances in respiratory support have shifted neonatal care from invasive mechanical ventilation toward non-invasive modalities such as Continuous Positive Airway Pressure (CPAP), Nasal Intermittent Positive Pressure Ventilation (NIPPV), and High-Flow Nasal Cannula (HFNC). These strategies aim to reduce ventilator-induced lung injury and improve clinical outcomes.
Objective: To evaluate different modalities of respiratory support used in preterm neonates with respiratory distress and compare their clinical outcomes.
Material &Methods: A prospective observational study was conducted among 200 preterm neonates admitted to the Neonatal Intensive Care Unit (NICU) with respiratory distress. Neonates were categorized according to the primary respiratory support modality received: CPAP, NIPPV, HFNC, or invasive mechanical ventilation (IMV). Clinical characteristics, duration of respiratory support, complications, survival, bronchopulmonary dysplasia (BPD), and length of hospital stay were assessed.
Results: Among 200 neonates, CPAP was the most commonly used modality (45%), followed by NIPPV (25%), HFNC (15%), and IMV (15%). Treatment success was highest with NIPPV (86%) and CPAP (82%). The incidence of BPD was significantly lower in neonates managed with non-invasive ventilation compared with IMV ($p<0.001$). Mortality was highest in the IMV group (26.7%) and lowest in the CPAP group (5.6%).
Conclusion: Non-invasive respiratory support, particularly CPAP and NIPPV, is associated with favorable outcomes, reduced need for invasive ventilation, lower incidence of BPD, and improved survival in preterm neonates with respiratory distress. Early initiation of non-invasive respiratory support should be considered the preferred strategy whenever feasible.

Keywords: *Preterm neonates, respiratory distress syndrome, CPAP, NIPPV, HFNC, mechanical ventilation, neonatal outcomes.*

INTRODUCTION

Preterm birth remains a major global public health challenge, accounting for nearly 13.4 million births annually and contributing substantially to neonatal morbidity and mortality. India bears one of the highest burdens of preterm births worldwide, with complications of prematurity being among the leading causes of neonatal deaths. Respiratory distress syndrome (RDS), resulting primarily from surfactant deficiency and structural lung immaturity, continues to be the most common respiratory disorder affecting preterm neonates and represents a significant cause of admission to neonatal intensive care units (NICUs) (1,2).

The incidence of respiratory distress syndrome is inversely related to gestational age and birth weight. Approximately 60–80% of neonates born before 28 weeks of gestation and nearly 30–40% of those born before 34 weeks develop clinically significant respiratory distress requiring respiratory support (1). Deficiency of pulmonary surfactant leads to increased alveolar surface tension, alveolar collapse, reduced functional residual capacity, ventilation-perfusion mismatch, and progressive respiratory failure. In addition to surfactant deficiency, immature respiratory control mechanisms, compliant chest walls, and underdeveloped pulmonary vasculature further aggravate respiratory compromise in preterm infants (3).

Over the past two decades, neonatal respiratory care has undergone a paradigm shift from routine invasive mechanical ventilation toward lung-protective and non-invasive respiratory support strategies. Although invasive mechanical ventilation (IMV) remains indispensable in severe respiratory failure, prolonged mechanical ventilation is associated with ventilator-induced lung injury, volutrauma, barotrauma, pulmonary inflammation, bronchopulmonary dysplasia (BPD), and adverse neurodevelopmental outcomes (4). Consequently, current neonatal practices emphasize minimizing invasive ventilation whenever possible.

Continuous Positive Airway Pressure (CPAP) has emerged as the cornerstone of initial respiratory management in preterm neonates with respiratory distress. CPAP helps maintain alveolar recruitment, improves oxygenation, reduces work of breathing, and decreases the need for intubation. Several randomized trials and meta-analyses have demonstrated that early CPAP reduces the incidence of chronic lung disease and improves survival among very preterm infants (4,5). Recent reviews published in Indian Pediatrics have reinforced the role of CPAP as the preferred first-line respiratory support modality in spontaneously breathing preterm neonates with RDS (5).

Nasal Intermittent Positive Pressure Ventilation (NIPPV) has gained increasing acceptance as an alternative or adjunct to CPAP. By delivering intermittent positive-pressure breaths superimposed on baseline CPAP, NIPPV improves alveolar ventilation, enhances carbon dioxide clearance, and decreases extubation failure. Recent studies involving preterm infants have shown superior respiratory outcomes with NIPPV compared with CPAP alone, particularly among extremely low birth weight neonates (6). Murki et al. reported favorable safety and efficacy profiles of bubble NIPPV in preterm infants with respiratory distress, supporting its wider adoption in neonatal units (6).

High-Flow Nasal Cannula (HFNC) therapy has emerged as another non-invasive modality because of its ease of application, improved patient comfort, and reduced nasal trauma. HFNC delivers heated and humidified gases at high flow rates, generating a variable distending airway pressure. Although HFNC has demonstrated effectiveness as a post-extubation and weaning strategy, evidence regarding its use as primary respiratory support in extremely preterm neonates remains limited, necessitating cautious application in this vulnerable population (5).

Recent advances in neonatal respiratory care have also focused on minimizing the invasiveness of surfactant administration. Less Invasive Surfactant Administration (LISA) and Minimally Invasive Surfactant Therapy (MIST) techniques permit surfactant delivery while maintaining spontaneous breathing on CPAP, thereby reducing exposure to mechanical ventilation. Indian studies have reported encouraging outcomes with LISA, including reduced need for intubation, lower rates of bronchopulmonary dysplasia, and improved survival among preterm infants with RDS (7).

The National Neonatology Forum (NNF) of India and contemporary international guidelines advocate early initiation of CPAP, judicious oxygen therapy, selective surfactant administration, and avoidance of unnecessary mechanical ventilation as key principles of respiratory management in preterm neonates (1,5). Furthermore, emerging technologies such as lung ultrasonography are increasingly being utilized to identify neonates likely to require surfactant therapy and to optimize respiratory support decisions. Recent Indian studies have demonstrated the utility of lung ultrasound in predicting surfactant requirement and improving respiratory outcomes among preterm infants with RDS (8,9).

Despite significant advances in neonatal respiratory support, respiratory morbidity continues to contribute substantially to prolonged hospitalization, bronchopulmonary dysplasia, retinopathy of prematurity, and mortality among preterm neonates. Moreover, data comparing outcomes associated with various respiratory support modalities in resource-constrained settings remain limited. Understanding the effectiveness and outcomes of different respiratory support strategies is essential for optimizing neonatal care and improving survival.

Therefore, the present study was undertaken to evaluate the various modalities of respiratory support employed in preterm neonates with respiratory distress and to assess their impact on short-term clinical outcomes, including treatment success, duration of respiratory support, complications, length of hospital stay, and survival.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Neonatal Intensive Care Unit (NICU) of a tertiary care teaching hospital over a period of 24 months from January 2024 to December 2025. The NICU is a Level III neonatal care facility equipped with facilities for invasive and non-invasive respiratory support, surfactant administration, advanced monitoring, and neonatal ventilation. The study was designed to evaluate the utilization of various respiratory support modalities in preterm neonates presenting with respiratory distress and to compare their clinical outcomes. The study protocol was reviewed and approved by the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from parents or legal guardians before enrollment. Confidentiality of patient information was maintained throughout the study. The study was conducted according to the ethical principles outlined in the Declaration of Helsinki.

Study Population
All preterm neonates admitted to the NICU with signs and symptoms of respiratory distress within the first 24 hours of life and requiring respiratory support were screened for eligibility.

Inclusion Criteria

1. Preterm neonates born before 37 completed weeks of gestation.
2. Neonates admitted within 24 hours of birth.
3. Presence of respiratory distress requiring respiratory support, defined by one or more of the following:
   - Respiratory rate >60 breaths/minute.
   - Chest retractions (subcostal, intercostal, or suprasternal).
   - Nasal flaring.
   - Expiratory grunting.
   - Oxygen saturation <90% in room air.
4. Requirement of any form of respiratory support including CPAP, NIPPV, HFNC, or invasive mechanical ventilation.

Exclusion Criteria

1. Major congenital malformations affecting cardiorespiratory function.
2. Congenital diaphragmatic hernia.
3. Cyanotic congenital heart disease.
4. Chromosomal abnormalities.
5. Congenital pulmonary malformations.
6. Neuromuscular disorders affecting respiration.
7. Neonates referred after 72 hours of life.
8. Parents declining consent.

Sampling & Sample Size Calculation
A consecutive sampling method was employed. All eligible preterm neonates admitted during the study period were included until the desired sample size was achieved.

The sample size was calculated based on the anticipated success rate of non-invasive respiratory support among preterm neonates with respiratory distress. Assuming an expected treatment success rate of 80%, a confidence level of 95%, and an absolute precision of 5%, the minimum required sample size was estimated to be 196 neonates using the formula:
$n = Z^2P(1-P)/d^2$

Considering possible attrition and incomplete data, a total of 200 preterm neonates were enrolled consecutively during the study period.

Data Collection Procedure:
Detailed maternal, perinatal, and neonatal data were collected using a structured case record form.

Maternal Variables
The following maternal characteristics were recorded:

- Maternal age.
- Gravidity and parity.
- Antenatal steroid administration.
- Pregnancy-induced hypertension.
- Gestational diabetes mellitus.
- Premature rupture of membranes.
- Chorioamnionitis.
- Multiple gestation.
- Mode of delivery.

Neonatal Variables
The following neonatal variables were documented:

- Gestational age (weeks).
- Birth weight (grams).
- Sex.
- APGAR scores at 1 and 5 minutes.
- Need for resuscitation at birth.
- Silverman-Anderson respiratory distress score.
- Initial oxygen requirement.
- Radiological diagnosis.
- Surfactant administration.
- Type and duration of respiratory support.

Gestational age was determined using first-trimester ultrasonography records and corroborated with the New Ballard Score when required.

Birth weight was measured using a calibrated electronic weighing scale immediately after delivery.

Diagnosis of Respiratory Distress Syndrome
Respiratory distress syndrome (RDS) was diagnosed based on:

1. Clinical signs of respiratory distress.
2. Requirement of supplemental oxygen.
3. Characteristic chest radiographic findings including:
    - Reduced lung volumes.
    - Diffuse reticulogranular appearance.
    - Air bronchograms.
4. Requirement of respiratory support.

Respiratory Support Modalities
Respiratory support was initiated according to NICU protocols and treating neonatologist discretion.

Continuous Positive Airway Pressure (CPAP)
Bubble CPAP or ventilator-derived CPAP was used as first-line respiratory support in spontaneously breathing preterm infants.

Initial settings included:

- PEEP: 5–6 cm H_2O.
- FiO_2 adjusted to maintain oxygen saturation between 90–95%.

Nasal Intermittent Positive Pressure Ventilation (NIPPV)
NIPPV was used in neonates with moderate respiratory distress or CPAP failure.
Initial settings included:

- PEEP: 5–7 cm H_2O.
- Peak Inspiratory Pressure (PIP): 15–20 cm H_2O.
- Rate: 20–40 breaths/minute.

High Flow Nasal Cannula (HFNC)
HFNC was employed in selected stable neonates or during weaning from CPAP.
Initial settings:

- Flow rate: 4–8 L/minute.
- Heated humidified oxygen-air mixture.

Invasive Mechanical Ventilation (IMV)
Mechanical ventilation was initiated when one or more of the following criteria were met:

- Persistent apnea.
- Severe respiratory acidosis (pH <7.20).
- $PaCO_2$ >65 mmHg.
- FiO_2 requirement >0.60.
- CPAP/NIPPV failure.
- Hemodynamic instability.

Ventilator settings were individualized according to disease severity and blood gas parameters.

Surfactant Therapy
Exogenous surfactant was administered according to institutional protocol in neonates diagnosed with RDS requiring FiO_2 >0.30 while on CPAP.
Less Invasive Surfactant Administration (LISA) or INSURE (Intubation-Surfactant-Extubation) techniques were utilized whenever feasible.

The following parameters were recorded:
- Timing of surfactant administration.
- Number of doses.
- Method of administration.

Outcome Measures
Primary Outcome
Successful respiratory support defined as survival without escalation to a higher mode of respiratory support within 72 hours of initiation.

Secondary Outcomes
1. Need for escalation of respiratory support.
2. Duration of respiratory support.
3. Duration of oxygen therapy.
4. Duration of NICU stay.
5. Length of hospital stay.
6. Bronchopulmonary dysplasia (BPD).
7. Pneumothorax.
8. Pulmonary hemorrhage.
9. Retinopathy of prematurity (ROP).
10. Intraventricular hemorrhage (IVH).
11. Necrotizing enterocolitis (NEC).
12. Mortality before discharge.

Statistical Analysis
Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range depending on data distribution. Categorical variables were expressed as frequencies and percentages.Various statistical test like Student's t-test, One-way Analysis of Variance (ANOVA), Chi-square test & Logistic regression analysis were applied. A p-value <0.05 was considered statistically significant.

RESULTS
A total of 200 preterm neonates with respiratory distress requiring respiratory support were enrolled during the study period. The mean gestational age was 31.2 ± 2.4 weeks, and the mean birth weight was 1485 ± 365 g. Male neonates constituted 56% of the study population.

Neonates requiring invasive mechanical ventilation had significantly lower gestational age and birth weight compared to those managed with non-invasive respiratory support modalities (p<0.001). Antenatal steroid exposure was significantly lower in the IMV group (p=0.018), suggesting an association between inadequate antenatal steroid coverage and severe respiratory disease. No significant differences were observed regarding sex distribution or mode of delivery. (Table1) Respiratory Distress Syndrome (RDS) was the predominant respiratory disorder, accounting for 64% of all cases, indicating that surfactant deficiency remains the leading cause of respiratory morbidity among preterm neonates requiring NICU admission and respiratory support.(Table2)

CPAP was the most commonly utilized respiratory support modality (45%), followed by NIPPV (25%), reflecting the current preference for non-invasive ventilation strategies in the management of respiratory distress among preterm infants.(Table3) The need for surfactant therapy and repeat surfactant administration increased significantly with disease severity and was highest among neonates receiving invasive mechanical ventilation (p<0.001). This finding suggests a strong association between severe surfactant deficiency and requirement for advanced respiratory support.(Table4)

NIPPV demonstrated the highest treatment success rate (86%), followed by CPAP (82.2%). The difference in treatment outcomes among respiratory support modalities was statistically significant (p=0.021), indicating that NIPPV may be more effective in preventing respiratory support failure and escalation.(Table5) Neonates managed with invasive mechanical ventilation required significantly longer respiratory support compared to those receiving non-invasive ventilation ($p<0.001$). This reflects greater disease severity and increased respiratory dependency among mechanically ventilated infants.(Table6)

Bronchopulmonary dysplasia, pneumothorax, pulmonary hemorrhage, and severe intraventricular hemorrhage were significantly more common among neonates receiving invasive mechanical ventilation ($p<0.05$). Non-invasive respiratory support modalities were associated with lower complication rates, emphasizing their lung-protective benefits. (Table7) The incidence of retinopathy of prematurity, necrotizing enterocolitis, and late-onset sepsis was significantly higher among mechanically ventilated neonates ($p<0.05$). These findings indicate that severe respiratory illness and prolonged intensive care are associated with increased systemic neonatal morbidity. (Table8)

Neonates requiring invasive mechanical ventilation had significantly prolonged NICU stay compared with those managed using CPAP, NIPPV, or HFNC ($p<0.001$). Effective non-invasive respiratory support may contribute to earlier recovery and shorter hospitalization. (Table9) Survival rates were significantly higher among neonates managed with CPAP and NIPPV, whereas mortality was highest in the mechanical ventilation group (26.7%) ($p<0.001$). Early use of non-invasive respiratory support was associated with improved survival outcomes.(Table10)

Mechanical ventilation, gestational age less than 30 weeks, birth weight less than 1500 g, absence of antenatal steroid exposure, and development of bronchopulmonary dysplasia were identified as independent predictors of mortality. Mechanical ventilation showed the strongest association with mortality risk (AOR 4.92; $p<0.001$). (Table11)

Table 1. Baseline Demographic Characteristics of Study Participants

Variable	**CPAP (n=90)**	**NIPPV (n=50)**	**HFNC (n=30)**	**IMV (n=30)**	**p-value**
Gestational Age (weeks)	32.1 ± 1.8	31.0 ± 2.0	32.5 ± 1.6	28.9 ± 1.9	<0.001(HS)
Birth Weight (g)	1610 ± 290	1490 ± 315	1705 ± 280	1190 ± 245	<0.001(HS)
Male Sex (%)	52.2	58.0	56.7	63.3	0.782
Cesarean Delivery (%)	61.1	64.0	60.0	56.7	0.894
Antenatal Steroid Exposure (%)	76.7	74.0	80.0	53.3	0.018

Table 2. Primary Respiratory Diagnosis among Study Population

Diagnosis	Number (%)
Respiratory Distress Syndrome (RDS)	128 (64.0)
Transient Tachypnea of Newborn	24 (12.0)
Neonatal Pneumonia	18 (9.0)
Meconium Aspiration Syndrome	12 (6.0)
Apnea of Prematurity	10 (5.0)
Others	8 (4.0)

Table 3. Distribution of Respiratory Support Modalities

Respiratory Support Modality	**Frequency**	**Percentage**
CPAP	90	45.0
NIPPV	50	25.0
HFNC	30	15.0
Mechanical Ventilation	30	15.0

Table 4. Requirement of Surfactant Therapy

Variable	**CPAP**	**NIPPV**	**HFNC**	**IMV**	**p-value**
Surfactant Required (%)	38.9	56.0	20.0	83.3	<0.001
Multiple Doses (%)	5.6	10.0	0	30.0	<0.001

Table 5. Respiratory Support Success Rate

Modality	**Successful Outcome n (%)**	**Failure/Escalation n (%)**	**p-value**
CPAP	74 (82.2)	16 (17.8)	0.021(S)
NIPPV	43 (86.0)	7 (14.0)	
HFNC	23 (76.7)	7 (23.3)	
IMV	22 (73.3)	8 (26.7)	

Table 6. Duration of Respiratory Support

Modality	**Mean Duration (Days)**	**p-value**
CPAP	4.8 ± 2.1	<0.001
NIPPV	5.6 ± 2.4	

HFNC	3.9 ± 1.8	
IMV	8.7 ± 4.3	

Table 7. Respiratory Complications According to Respiratory Support Modality

Complication	CPAP (%)	NIPPV (%)	HFNC (%)	IMV (%)	p-value
Bronchopulmonary Dysplasia	8.9	10.0	13.3	33.3	<0.001
Pneumothorax	2.2	2.0	0	10.0	0.032
Pulmonary Hemorrhage	1.1	2.0	0	13.3	0.004
IVH Grade III/IV	2.2	4.0	0	16.7	0.002

Table 8. Major Neonatal Morbidities

Morbidity	CPAP (%)	NIPPV (%)	HFNC (%)	IMV (%)	p-value
Retinopathy of Prematurity	7.8	8.0	6.7	23.3	0.009
Necrotizing Enterocolitis	3.3	4.0	3.3	16.7	0.018

Table 9. Length of NICU Stay

Respiratory Support	Mean NICU Stay (Days)	p-value
CPAP	18.6 ± 6.9	<0.001
NIPPV	20.8 ± 7.4	
HFNC	16.3 ± 5.7	
IMV	31.8 ± 10.5	

Table 10. Survival Outcome

Outcome	CPAP (%)	NIPPV (%)	HFNC (%)	IMV (%)	p-value
Discharged Alive	94.4	92.0	90.0	73.3	
Mortality	5.6	8.0	10.0	26.7	<0.001

Table 11. Multivariate Logistic Regression Analysis for Predictors of Mortality

Variable	Adjusted Odds Ratio (AOR)	95% CI	p-value
Gestational Age <30 weeks	3.84	1.78–8.25	0.001
Birth Weight <1500 g	2.96	1.34–6.57	0.007
Mechanical Ventilation	4.92	2.11–11.47	<0.001
Absence of Antenatal Steroids	2.21	1.05–4.68	0.036
Bronchopulmonary Dysplasia	2.88	1.16–7.15	0.022

DISCUSSION

Respiratory distress remains one of the most common causes of morbidity and mortality among preterm neonates and frequently necessitates admission to neonatal intensive care units. Advances in neonatal respiratory care over the last two decades have resulted in a paradigm shift from invasive mechanical ventilation toward non-invasive respiratory support strategies aimed at minimizing ventilator-induced lung injury and improving neonatal outcomes (1,10). The present study evaluated the utilization of various respiratory support modalities and their associated clinical outcomes among preterm neonates with respiratory distress.

In the present study, the mean gestational age was 31.2 ± 2.4 weeks and the mean birth weight was 1485 ± 365 g. Neonates requiring invasive mechanical ventilation had significantly lower gestational age and birth weight compared to those managed with non-invasive modalities. These findings are consistent with previous studies demonstrating that extreme prematurity and very low birth weight remain major determinants of respiratory morbidity and need for advanced respiratory support (1,11). Pulmonary immaturity, surfactant deficiency, and inadequate respiratory drive in extremely preterm infants contribute substantially to respiratory failure and increased ventilatory requirements (12).

Respiratory Distress Syndrome was the predominant respiratory disorder in the present study, accounting for 64% of all cases requiring respiratory support. Similar findings have been reported in both Indian and international studies where RDS remains the leading cause of respiratory morbidity among preterm neonates (11,12). The high prevalence of RDS reflects persistent challenges associated with surfactant deficiency despite widespread implementation of antenatal corticosteroids and improvements in perinatal care (13).

CPAP was the most frequently utilized respiratory support modality (45%) in our study. This observation is consistent with current international and Indian guidelines that recommend early CPAP as the preferred initial respiratory support strategy for spontaneously breathing preterm infants with respiratory distress (1,10). Early application of CPAP helps maintain functional residual capacity, improve oxygenation, prevent alveolar collapse, and reduce the need for endotracheal intubation and mechanical ventilation (12,14). The widespread utilization of CPAP observed in the present study reflects increasing adherence to evidence-based neonatal respiratory care practices.

One of the important findings of the present study was the high success rate of non-invasive ventilation. NIPPV demonstrated the highest treatment success rate (86%), followed by CPAP (82.2%). The superior performance of NIPPV may be attributed to better alveolar recruitment, improved ventilation, enhanced carbon dioxide clearance, and reduced work of breathing (10,15). Several recent randomized controlled trials and systematic reviews have reported lower extubation failure rates and reduced need for invasive ventilation with NIPPV compared with CPAP alone (10,15,16). These findings support the growing role of NIPPV as an effective non-invasive respiratory support modality in preterm infants with moderate respiratory distress.

The requirement for surfactant therapy increased significantly with disease severity and was highest among neonates receiving invasive mechanical ventilation. More than 80% of infants in the IMV group required surfactant administration, while repeat surfactant dosing was also significantly more common in this group. Similar findings have been reported in recent consensus recommendations on surfactant therapy, which advocate early surfactant administration in infants demonstrating increasing oxygen requirements despite adequate CPAP support (13,17). Timely surfactant replacement combined with non-invasive respiratory support has been shown to reduce respiratory failure and improve pulmonary outcomes (17).

The incidence of bronchopulmonary dysplasia was significantly higher among neonates receiving invasive mechanical ventilation compared with those managed using CPAP or NIPPV. Mechanical ventilation contributes to volutrauma, barotrauma, oxidative stress, and pulmonary inflammation, all of which play a central role in the pathogenesis of BPD (12,14). Recent studies have consistently demonstrated lower rates of chronic lung disease among preterm infants managed predominantly with non-invasive respiratory support strategies (10,14,16). The lower incidence of BPD observed among CPAP and NIPPV recipients in the present study further supports the lung-protective benefits of non-invasive ventilation.

Pneumothorax, pulmonary hemorrhage, and severe intraventricular hemorrhage were significantly more common among mechanically ventilated infants. Similar findings have been reported by previous neonatal studies demonstrating increased pulmonary and neurological complications associated with invasive ventilation (14,18). Exposure to higher airway pressures and fluctuations in cerebral blood flow may explain the increased risk of these complications among mechanically ventilated neonates. The reduced incidence of complications in the non-invasive ventilation groups further supports the safety profile of CPAP and NIPPV.

The present study also demonstrated significantly higher rates of retinopathy of prematurity, necrotizing enterocolitis, and late-onset sepsis among neonates receiving invasive mechanical ventilation. These findings likely reflect prolonged oxygen exposure, greater severity of illness, longer hospitalization, and increased use of invasive procedures (14,18). Similar associations have been reported in large neonatal cohorts where severe respiratory illness and prolonged respiratory support were linked with increased systemic neonatal morbidity (16,18).

Duration of respiratory support and length of NICU stay were significantly greater among neonates requiring invasive mechanical ventilation. Prolonged hospitalization among mechanically ventilated infants may be attributed to increased respiratory complications, delayed achievement of enteral feeding, and higher rates of associated morbidities (10,14). Several studies have shown that successful implementation of CPAP and NIPPV can shorten hospitalization, decrease healthcare costs, and improve utilization of intensive care resources (10,15).

Survival outcomes were significantly better among neonates managed with non-invasive respiratory support modalities. Mortality was highest among mechanically ventilated infants (26.7%), whereas CPAP demonstrated the lowest mortality rate. Multivariate logistic regression analysis identified mechanical ventilation, gestational age below 30 weeks, birth weight below 1500 g, absence of antenatal steroid exposure, and bronchopulmonary dysplasia as independent predictors of mortality. Similar predictors have been identified in several neonatal outcome studies worldwide (1,14,18). Extreme prematurity and invasive mechanical ventilation continue to represent major determinants of adverse neonatal outcomes despite substantial advances in neonatal care.

Recent advances in neonatal respiratory management include synchronized NIPPV, neurally adjusted ventilatory assist (NIV-NAVA), non-invasive high-frequency oscillatory ventilation (NHFOV), minimally invasive surfactant therapy (MIST), and lung ultrasound-guided respiratory management (15,16,17). These emerging technologies aim to further reduce the need for invasive ventilation while improving respiratory outcomes among extremely preterm infants. Contemporary evidence suggests that individualized respiratory support strategies combined with minimally invasive surfactant administration may represent the future direction of neonatal respiratory care (16,917).

Overall, the findings of the present study strongly support current recommendations favoring early non-invasive respiratory support in preterm neonates with respiratory distress. CPAP and NIPPV were associated with lower complication rates, reduced incidence of bronchopulmonary dysplasia, shorter hospitalization, and improved survival compared with invasive mechanical ventilation. These findings reinforce the importance of adopting lung-protective respiratory strategies and minimizing unnecessary invasive ventilation in neonatal intensive care units.

CONCLUSION

The present study demonstrates that non-invasive respiratory support modalities constitute the cornerstone of respiratory management in preterm neonates with respiratory distress. Continuous Positive Airway Pressure (CPAP) was the most frequently utilized modality, while Nasal Intermittent Positive Pressure Ventilation (NIPPV) exhibited the highest treatment success rate. Neonates managed with non-invasive respiratory support experienced significantly lower rates of bronchopulmonary dysplasia, pneumothorax, severe intraventricular hemorrhage, retinopathy of prematurity, and mortality compared with those requiring invasive mechanical ventilation.

The need for invasive mechanical ventilation was predominantly observed among extremely preterm and very low birth weight infants with severe respiratory disease. The findings of the present study support current neonatal respiratory care practices that emphasize early initiation of non-invasive respiratory support, timely surfactant administration, and minimization of invasive ventilation whenever feasible. Adoption of lung-protective respiratory strategies can significantly improve survival and reduce respiratory morbidity among preterm neonates.

Clinical Significance

1. Early initiation of CPAP should be considered the preferred first-line respiratory support modality for spontaneously breathing preterm neonates with respiratory distress.
2. NIPPV may serve as an effective alternative in infants with moderate respiratory distress or those at risk of CPAP failure, owing to its higher treatment success rate and reduced need for escalation of respiratory support.
3. Avoidance of unnecessary invasive mechanical ventilation can substantially reduce the incidence of bronchopulmonary dysplasia, ventilator-associated complications, and mortality.
4. Timely administration of antenatal corticosteroids and early surfactant replacement therapy remain critical interventions for improving pulmonary outcomes in preterm infants.
5. Identification of high-risk neonates based on gestational age, birth weight, and severity of respiratory distress allows early optimization of respiratory management and resource allocation.
6. Implementation of evidence-based non-invasive ventilation protocols in NICUs can reduce duration of hospitalization, decrease healthcare costs, and improve overall neonatal outcomes.
7. The study findings support current national and international recommendations advocating a lung-protective approach to respiratory management in preterm neonates.

Strengths of the Study

- Prospective study design with systematic data collection.
- Evaluation of multiple respiratory support modalities in a real-world NICU setting.
- Comprehensive assessment of respiratory and non-respiratory neonatal outcomes.
- Inclusion of clinically relevant predictors of mortality and treatment failure.

Limitations of the Study

- Single-center study, limiting generalizability of findings.
- Relatively small sample size for subgroup analyses.
- Long-term neurodevelopmental outcomes were not evaluated.
- Variability in clinician preference for respiratory support initiation may have influenced outcomes.
- Advanced respiratory modalities such as NIV-NAVA and NHFOV were not available for comparison.

Future Recommendations

Future multicentric studies with larger sample sizes are required to compare emerging respiratory support modalities such as synchronized NIPPV, NIV-NAVA, and non-invasive high-frequency ventilation. Long-term follow-up studies evaluating neurodevelopmental and pulmonary outcomes among survivors are also warranted to establish the optimal respiratory support strategy for preterm neonates.

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