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Original Article

Impact of High-Flow Nasal Cannula Oxygen on Respiratory Distress in Infants with Bronchiolitis

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ABSTRACT

Background: High-flow nasal cannula (HFNC) therapy has emerged as a promising non-invasive respiratory support modality for managing pediatric bronchiolitis, but evidence regarding its effectiveness in resource-limited hospital settings remains limited.
Objectives: To assess the clinical efficacy of HFNC therapy in infants and young children with bronchiolitis and to evaluate its impact on reducing intubation rates and length of pediatric intensive care unit (PICU) stay.
Methods: A prospective observational study was conducted enrolling 108 children aged 1 month to 2 years with respiratory distress due to bronchiolitis (Wang Bronchiolitis Severity Score ≥4). Patients received HFNC therapy with flow rates of 2 L/kg/min . Clinical parameters including heart rate, respiratory rate, oxygen saturation, and Wang Bronchiolitis Severity Score(WBSS) were documented at baseline and at 1, 6, 12, and 24 hours of therapy.
Results: Of 108 children studied (mean age 8.8±0.9 months; 51.9% male), HFNC therapy resulted in significant reductions in heart rate ($p<0.01$), respiratory rate ($p<0.01$), and WBSS within 12-24 hours of initiation. At 24 hours, 61.1% of patients achieved a severity score ≤1. Invasive mechanical ventilation was required in only 7.4% (n=8) of patients, while 92.6% (n=100) managed successfully without escalation. Median duration of HFNC therapy was 24 hours, with median PICU stay of 2 days. No serious adverse events attributable to HFNC were documented.
Conclusions: HFNC therapy effectively reduces respiratory distress parameters and significantly decreases the need for invasive mechanical ventilation in children with moderate bronchiolitis, offering a safe and well-tolerated non-invasive respiratory support option in hospital settings.

Keywords: *Bronchiolitis, high-flow nasal cannula, non-invasive ventilation, pediatric respiratory distress, PICU stay.*

INTRODUCTION

Acute viral bronchiolitis remains the most common cause of acute lower respiratory tract infection and hospitalization in infants under two years of age globally[1]. The pathophysiology involves inflammation of bronchioles leading to mucus plugging, airway obstruction, and ventilation-perfusion mismatch, clinically manifesting as respiratory distress, wheezing, and hypoxemia[2]. While supportive care including oxygen therapy and adequate nutrition form the cornerstone of management as per American Academy of Pediatrics and UK national guidelines, the management of severe cases requiring respiratory support has evolved significantly[3].

Traditional low-flow oxygen therapy through nasal cannula has inherent limitations in pediatric patients, particularly at higher flow rates, as non-humidified oxygen can dry and cool the airway, exacerbating discomfort and airway obstruction[4]. Noninvasive positive pressure ventilation (NIPPV) methods such as continuous positive airway pressure

(CPAP) reduce intubation rates but are often poorly tolerated in infants due to discomfort, nasal trauma, and requirement for sedation[5]. Endotracheal intubation with mechanical ventilation, while life-saving in severe cases, carries significant complications including ventilator-associated infections and prolonged PICU stays[6].

High-flow nasal cannula (HFNC) therapy has emerged as an attractive alternative providing heated and humidified oxygen at high flow rates (>2 L/min in infants, >6 L/min in children), delivering oxygen with approximately 100% relative humidity at temperatures between 34-37°C[7]. The physiological benefits of HFNC include: (i) washout of nasopharyngeal dead space reducing CO2 rebreathing, (ii) generation of positive end-expiratory pressure (approximately 6 cm H2O), (iii) improved mucociliary clearance through optimal humidity, and (iv) superior patient tolerance compared to other non-invasive modes[8].

Several randomized controlled trials have demonstrated variable evidence regarding HFNC efficacy in bronchiolitis. The HFWHO Australia study and the trial by Franklin et al. reported reduced intubation rates with HFNC compared to standard oxygen therapy[9][10]. However, more recent studies, including those by Choi et al. and Kepreotes et al., have provided inconclusive evidence, suggesting comparable outcomes between HFNC and standard therapy in certain cohorts[11][12]. Despite mixed evidence on superiority, HFNC has gained significant popularity in pediatric practice due to its ease of administration and excellent patient tolerance, particularly when compared with CPAP.

Evidence regarding HFNC safety and efficacy in resource-limited tertiary care hospital settings, where pediatric ICU-trained staff and ongoing educational resources may be limited, remains sparse[13]. Additionally, the immediate physiological effects of HFNC on respiratory effort and clinical parameters in the first 24 hours warrant further investigation. This prospective observational study was conducted to evaluate the clinical efficacy of HFNC therapy in infants and young children with bronchiolitis in a hospital-based PICU setting.

METHODS

Study Design: Prospective observational study

Study Period: June 2023 to December 2024

Study Setting: Pediatric Intensive Care Unit (PICU), Gandhi Hospital, Secunderabad, Telangana, India

Study Population: Children aged 1 month to 2 years admitted to PICU with respiratory distress due to bronchiolitis

Sample Size: 108 participants

Inclusion Criteria:

- Children aged 1 month to 2 years
- Clinical diagnosis of bronchiolitis with respiratory distress
- Wang Bronchiolitis Severity Score ≥4

Exclusion Criteria:

- Age <1 month or >2 years
- Focal lung signs or radiological evidence of pneumonia
- Hemodynamic instability or requirement for vasopressors
- Glasgow Coma Scale score ≤8
- Urgent need for endotracheal intubation at admission
- Upper airway obstruction or craniofacial malformations

METHODOLOGY

The study was approved by the Institutional Ethics Committee (Ethics approval vide Rc No. IEC/GMC/2023/08/202 dated 29-03-2023. Written informed consent was obtained from parents/guardians of all enrolled children.

All children meeting inclusion criteria were assessed clinically and their respiratory distress severity was graded using the Wang Bronchiolitis Severity Score (incorporating respiratory rate, retractions, wheezing, accessory muscle use, and general condition). Diagnosis of bronchiolitis was confirmed by standard clinical criteria and supported by nasopharyngeal aspirate testing for respiratory syncytial virus (RSV) and other viral pathogens as available.

HFNC therapy was initiated using the Fisher and Paykel Airvo 2 device. Flow rates were determined using body weight-based calculation: 2 L/kg/min for infants ≤10 kg (maximum 20 L/min), and additional 0.5 L/kg/min for each kilogram above 10 kg (maximum 30 L/min for children). Initial FiO_2 was titrated to achieve peripheral oxygen saturation (SpO_2) >92%, with maximum FiO_2 limited to 60%.

Clinical parameters were documented at baseline (before HFNC initiation) and at 1, 6, 12, and 24 hours of therapy:

- Vital signs (heart rate, respiratory rate, oxygen saturation, temperature)
- Fraction of inspired oxygen (FiO_2)
- Flow rate (L/kg/min)
- Wang Bronchiolitis Severity Score (WBSS)

Treatment Response Criteria:

- **Success:** Significant decrease in heart rate (≥20%), respiratory rate (≥20%), and WBSS improvement within 1 hour with clinical stabilization within 24 hours
- **Failure:** Absence of improvement in WBSS after 1-6 hours of therapy, requiring escalation to non-invasive or invasive ventilation

For responding patients, HFNC was continued and gradually weaned by reducing flow to 1 L/kg/min and FiO_2 to room air (21%), with discontinuation when WBSS ≤3 and clinical stabilization was achieved. Duration of HFNC therapy, total PICU stay, requirement for invasive mechanical ventilation, and clinical outcomes were recorded.

Statistical Analysis:
Descriptive statistics were used to summarize baseline characteristics and outcomes. Changes in vital signs and clinical parameters over time were analyzed using appropriate statistical tests with significance set at $p<0.05$.

RESULTS

Patient Characteristics

Of 108 children enrolled, 56 (51.9%) were male and 52 (48.1%) female. The mean age was 8.8±0.9 months (range 1-24 months), with 41.7% (n=45) aged 6-10 months, representing the highest-risk group for severe bronchiolitis.

Baseline clinical characteristics reflected moderate to severe respiratory distress: mean heart rate was 140.4±18.2 bpm, mean respiratory rate was 58.6±8.7 breaths/min, and mean SpO_2 was 90.2±2.1%. General condition at presentation revealed 62% (n=67) of children were irritable, 17.6% (n=19) were lethargic, and 20.4% (n=22) were in normal condition. Regarding respiratory effort, 38.9% (n=42) had intercostal retractions alone, while 20.4% (n=22) exhibited severe retractions accompanied by nasal flaring. Baseline Wang Bronchiolitis Severity Score ranged from 4 to 12 (mean 8.4±1.8), with highest frequency at scores 9 (19.4%, n=21) and 8 (17.6%, n=19), indicating moderate to severe disease.

HFNC Therapy Administration

HFNC therapy was initiated on day 1 of admission in 79.6% (n=86) of cases and on day 2 in 20.4% (n=22) of cases. Initial FiO_2 settings were 40% in 50.9% (n=55), 50% in 30.6% (n=33), and 60% in 18.5% (n=20) of patients, titrated according to oxygenation requirements.

Response to HFNC Therapy

Vital Signs Response:
Significant improvements in vital parameters were observed within 1 hour of HFNC initiation:

Table 1: Changes in vital signs during HFNC therapy (n=108)

Parameter	Baseline	1 Hour	6 Hours	24 Hours
Heart Rate (bpm)	140.4±18.2	132.1±15.6	118.7±13.4	105.3±11.2
Respiratory Rate (breaths/min)	58.6±8.7	52.3±8.1	45.8±7.9	38.2±6.5
SpO_2 (%)	90.2±2.1	93.1±2.4	95.2±1.8	96.4±1.2

Clinical Severity Response:
Wang Bronchiolitis Severity Score showed progressive improvement across all time points:

Table 2: Wang Bronchiolitis Severity Score response to HFNC therapy

Time Point	Mean WBSS	Median WBSS	Range	% Score ≤3
Baseline	8.4±1.8	9	4-12	0
1 Hour	7.2±1.9	8	3-11	11.1
6 Hours	5.8±2.2	6	1-11	34.9
12 Hours	3.5±2.4	2	0-8	49.1
24 Hours	1.8±2.1	1	0-7	61.1

At 24 hours of HFNC therapy, 38% (n=41) of children achieved WBSS of 1, and 23.1% (n=25) achieved WBSS of 0, indicating substantial clinical improvement.

Duration of Therapy and PICU Stay
The duration of HFNC therapy varied based on individual clinical response:

- 7.4% (n=8) required 6 hours
- 5.6% (n=6) required 12 hours
- 48.1% (n=52) required 24 hours of therapy
- 23.1% (n=25) required 72 hours
- 15.7% (n=17) required 48 hours

Median duration of HFNC therapy was 24 hours (interquartile range 24-48 hours). Length of PICU stay ranged from 1 to 6 days, with 45.4% (n=49) staying for 2 days, 20.4% (n=22) for 3 days, and 17.6% (n=19) for 4 days. Median PICU stay was 2 days.

Primary Outcome: Intubation Rates
The primary efficacy endpoint demonstrated that invasive mechanical ventilation was required in only 7.4% (n=8) of children, while 92.6% (n=100) successfully managed their respiratory distress without escalation to invasive support. Among the 8 children requiring intubation, 5 had baseline WBSS ≥11, and all had lethargy or severely compromised general condition at presentation, representing the most severely ill subset. All 8 intubated patients recovered without mortality or major complications.

Safety Profile
No serious adverse events attributable to HFNC therapy were documented during the study period. Mild adverse events included transient epistaxis (n=2, 1.9%) and localized nasal irritation (n=1, 0.9%), both resolving without intervention. No pneumothorax, barotrauma, or other serious complications were observed.

DISCUSSION
This prospective observational study of 108 infants and young children with bronchiolitis treated with HFNC therapy demonstrates rapid and sustained clinical improvement in respiratory parameters, with successful avoidance of invasive ventilation in 92.6% of cases. These findings underscore the effectiveness of HFNC as a non-invasive respiratory support modality in hospital-based pediatric intensive care.

Efficacy Comparison with Literature:
The intubation rate of 7.4% in the present cohort is favorably low compared to historical data and supports findings from several meta-analytical reviews. Dafydd et al.[14], in a systematic review and meta-analysis of 13 trials, reported that HFNC reduces treatment failure compared to standard oxygen therapy with an OR of 0.50 (95% CI 0.26-0.95). Similarly, Cao et al.[15], analyzing 12 studies involving 1,134 children, found that HFNC reduced treatment failure rates (RR 0.62, 95% CI 0.40-0.96) and decreased respiratory rates compared to standard oxygen therapy. The Franklin et al. randomized controlled trial in 2018 with 255 infants demonstrated HFNC effectiveness in reducing escalation of care in moderate bronchiolitis[10].

The rapid response observed in vital signs within 1 hour is consistent with the physiological mechanisms of HFNC. The significant reduction in heart rate (8.3 bpm decrease in first hour; 14.5% reduction by 24 hours) and respiratory rate (6.3 breaths/min in first hour; 34.8% reduction by 24 hours) reflects reduced work of breathing. These improvements parallel findings reported by Surabhi et al.[16], who similarly documented substantial reductions in respiratory effort shortly after HFNC initiation.

Patient Tolerability and Safety:
An important advantage demonstrated in the present study is the superior patient tolerability of HFNC. The incidence of adverse events was minimal (2.8%, n=3), with only mild, self-limited epistaxis and nasal irritation, contrasting with the higher adverse event rates reported with CPAP. In direct comparisons, Catano-Jaramillo et al.[17] found that CPAP was associated with significantly more adverse events (RR 1.83, 95% CI 1.18-2.84) compared to HFNC, primarily nasal trauma requiring intervention or causing discomfort.

Furthermore, the absence of requirement for sedation in HFNC-treated patients is noteworthy for pediatric practice. Non-invasive ventilation modalities like CPAP and BiPAP often necessitate sedation to maintain patient-device synchronization and compliance, introducing additional risks of medication-related adverse effects. HFNC's open-system design and superior tolerance eliminate this requirement in the majority of cases, reducing medication exposure in vulnerable infants.

Outcomes and Resource Utilization:
The median PICU stay of 2 days in the present cohort reflects efficient clinical management and reduced resource utilization. This is particularly significant in resource-limited settings where PICU bed availability is constrained. The study aligns with observations by Kumar et al.[18] and Van Winkle et al.[13], who reported favorable outcomes with

HFNC in non-tertiary hospital settings and community hospitals, suggesting that HFNC can be safely deployed beyond tertiary academic centers when appropriate monitoring systems are in place.

Clinical Application in Resource-Limited Settings:
The present study was conducted in a tertiary care hospital in India with PICU facilities and dedicated nursing staff but without the extensive subspecialist support available at major academic medical centers globally. The findings demonstrate that HFNC can be effectively and safely utilized in such settings, providing a valuable non-invasive respiratory support option. The ease of HFNC administration compared to other non-invasive ventilation modalities (no requirement for tight-fitting interfaces, minimal training period) makes it particularly suitable for deployment in resource-limited contexts[19].

Study Limitations:
Several limitations should be acknowledged. First, the study was observational without a control group, limiting definitive conclusions regarding superiority over other interventions. Second, the hospital-based setting limits generalizability to community settings. Third, the study did not compare HFNC directly with CPAP or other non-invasive modalities, preventing head-to-head efficacy comparisons. Fourth, long-term follow-up data regarding complications and respiratory outcomes after discharge were not collected. Fifth, cost-effectiveness analysis was not performed, which would be valuable for resource-limited settings.

Implications for Clinical Practice:
The findings support the positioning of HFNC as a first-line non-invasive respiratory support option in pediatric bronchiolitis management, particularly when CPAP is contraindicated or poorly tolerated. The rapid response within 1 hour provides clinicians with an early indicator of therapeutic benefit, permitting timely assessment of response. Careful patient selection, with exclusion of critically ill children requiring urgent intubation, and appropriate monitoring protocols remain essential for safe deployment in all settings.

CONCLUSIONS

HFNC therapy effectively reduces respiratory distress parameters (heart rate, respiratory rate, and clinical severity scores) and significantly decreases the requirement for invasive mechanical ventilation in children aged 1 month to 2 years with bronchiolitis. With an intubation rate of 7.4% and excellent patient tolerance profile characterized by minimal adverse events and no requirement for sedation, HFNC emerges as a safe, effective, and patient-friendly non-invasive respiratory support modality for pediatric bronchiolitis.

The rapid clinical response within the first 24 hours of therapy enables timely assessment of treatment efficacy and guides clinical decisions regarding continuation, adjustment, or escalation of respiratory support. The association with shorter PICU and hospital stays suggests potential benefits for healthcare resource utilization.

Conflicts of Interest :None

Source of Funding : Nil

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