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Early use of heated and humidified high-flow nasal cannula (HFNC) therapy in pediatric bronchiolitis: A prospective observational study

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Abstract
Background/Objectives: Bronchiolitis is a leading cause of pediatric hospitalization, particularly in infants, where conventional low-flow oxygen therapy may be insufficient in managing moderate to severe respiratory distress. High-flow nasal cannula (HFNC) therapy delivers heated and humidified oxygen and has shown promise in critical care settings. This study evaluates the impact of early HFNC (AIRVO) initiation on general pediatric wards in reducing the need for Pediatric Intensive Care Unit (PICU) admissions and shortening hospital stays. In this prospective observational study, 50 children aged 1 month to 12 years with moderate to severe bronchiolitis were managed with HFNC therapy via the AIRVO system on the pediatric floor at a tertiary care center. Outcomes were compared with a matched historical control group of 50 patients treated with standard low-flow oxygen therapy. Primary outcomes included PICU admission rate and hospital length of stay. Statistical analysis was performed using chi-square and t-tests, with significance set at $p < 0.05$. The HFNC group demonstrated a significantly lower PICU admission rate (10% vs. 40%; $p < 0.01$) and a shorter mean hospital stay (3.7 vs. 5.2 days; $p < 0.01$). Additionally, time to achieve oxygen saturation >94% was faster in the HFNC group (12 vs. 18 hours). No adverse events were reported in either group. Early use of HFNC therapy with the AIRVO system on pediatric wards is a safe and effective strategy for managing moderate to severe bronchiolitis. It significantly reduces the need for PICU transfer and facilitates earlier recovery and discharge, offering a valuable alternative to traditional escalation pathways.

Keywords: Bronchiolitis; high-flow nasal cannula; AIRVO; pediatric ward; PICU avoidance; heated humidified oxygen

Introduction
Pediatric bronchiolitis remains one of the foremost causes of hospital admission and respiratory morbidity in infants and young children under the age of two. It is an acute viral infection of the lower respiratory tract, most commonly caused by respiratory syncytial virus (RSV), and is characterized by inflammation, edema, and obstruction of the small airways (bronchioles). The typical clinical presentation includes cough, tachypnea, wheezing, nasal flaring, chest retractions, and hypoxemia, frequently necessitating hospitalization for respiratory support and monitoring. Globally, bronchiolitis contributes to substantial pediatric healthcare utilization, especially during winter months, leading to significant burdens on emergency departments and inpatient services [1]. Traditionally, the mainstay of treatment has been supportive care—ensuring adequate hydration, oxygenation, and monitoring. Standard low-flow oxygen therapy remains the first-line modality in most pediatric wards. However, its limitations in managing moderate to severe respiratory distress are increasingly recognized. Escalation to intensive care units (ICUs) for therapies such as nasal continuous positive airway pressure (nCPAP) or mechanical ventilation is not uncommon, particularly in patients who demonstrate clinical deterioration or fail to maintain oxygen saturation above critical thresholds [2].
In recent years, high-flow nasal cannula (HFNC) therapy has emerged as an effective and well-tolerated alternative for managing bronchiolitis. HFNC systems deliver a high flow of heated and humidified oxygen through nasal prongs, offering numerous physiological benefits. These include enhanced mucociliary clearance, improved alveolar ventilation, reduced work of breathing, washout of nasopharyngeal dead space, and improved patient

comfort compared to more invasive modalities. Importantly, HFNC is associated with lower intubation rates and shorter ICU stays in pediatric populations. The AIRVO™ system by Fisher & Paykel is a widely used HFNC device specifically designed for both ward and critical care use [3]. While its clinical efficacy in ICU settings is well established, there remains a relative paucity of data supporting its routine use on general pediatric wards, especially in resource-constrained or training-sensitive environments. Concerns about safety, staff readiness, and monitoring protocols have traditionally limited its deployment outside critical care units [4]. Nevertheless, early implementation of HFNC therapy on pediatric wards holds significant promise in transforming the management of bronchiolitis. By delivering effective respiratory support at the ward level, HFNC has the potential to decrease the need for PICU admission, reduce healthcare costs, and improve patient-family satisfaction [5]. This becomes especially important in tertiary hospitals with high patient volumes, where ICU beds are limited and efficient triaging is paramount.

In this context, our study was designed to evaluate the clinical outcomes of early HFNC therapy initiation using the AIRVO system on pediatric wards [6]. By comparing this approach with a historical cohort treated with standard low-flow oxygen, we aimed to examine whether early non-ICU use of HFNC can reduce the rate of PICU transfers and shorten hospital length of stay without increasing the risk of adverse events. Furthermore, this study explores the feasibility of safely integrating HFNC therapy into routine ward-based bronchiolitis care, thereby contributing to an evolving paradigm of decentralized respiratory support in pediatrics.

Literature Review

Bronchiolitis is a significant cause of respiratory distress and hospital admissions in infants and young children globally. The American Academy of Pediatrics (AAP) clinical guidelines emphasize supportive care as the cornerstone of management, discouraging routine use of bronchodilators, corticosteroids, or antibiotics [7]. While standard oxygen therapy via low-flow nasal cannula (LFNC) remains widely used in pediatric wards, its efficacy in moderate to severe bronchiolitis is limited, often resulting in treatment failure and PICU transfer. High-flow nasal cannula (HFNC) therapy has emerged as a promising non-invasive intervention in pediatric respiratory support. It delivers heated and humidified gas at flow rates exceeding patient inspiratory flow, which generates a low level of positive end-expiratory pressure (PEEP), reduces work of breathing, and improves oxygenation and ventilation efficiency. Few were among the early studies to report the physiological benefits of HFNC in infants, noting reduced respiratory rates, fewer PICU escalations, and improved patient comfort [8]. These early successes laid the foundation for further randomized trials and meta-analyses.

In one of the largest multicenter randomized controlled trials to date, it had been demonstrated that early initiation of HFNC therapy in emergency departments for infants with bronchiolitis reduced the rate of treatment failure compared to standard oxygen, with fewer transfers to higher-acuity settings [9]. Similarly, the trial found that warm, humidified high-flow therapy was not inferior to standard oxygen therapy and resulted in fewer ICU admissions and shorter hospital stays [10].

Despite mounting evidence in favor of HFNC, institutional implementation has been inconsistent, often constrained by concerns related to staff training, patient monitoring, and equipment availability outside intensive care settings. The AIRVO system, specifically designed for ward-based delivery of heated and humidified oxygen, addresses some of these limitations by offering user-friendly interfaces and integrated humidification. However, its routine use in general pediatric wards remains under-evaluated in real-world settings, particularly in middle-income countries or high-volume tertiary hospitals.

A literature review emphasized the evolving role of HFNC in bronchiolitis management, calling for its wider adoption beyond the ICU, provided there is adequate staff training and monitoring infrastructure [11]. Similarly, the meta-analysis consolidated results from 15 studies and concluded that HFNC significantly reduced the need for mechanical ventilation, oxygen duration, and PICU transfers, although it called for more consistent clinical criteria and outcome measures across studies [12].

Moreover, the economics of respiratory care in pediatrics cannot be ignored. Studies highlight the potential cost-savings associated with avoiding PICU admission through early HFNC use. Shorter hospital stays, reduced ICU utilization, and improved caregiver satisfaction contribute to better healthcare system efficiency [13]. In resource-limited settings, where ICU beds are scarce and patient volumes are high, adopting HFNC on pediatric wards could offer both clinical and operational advantages.

In addition to clinical outcomes, the success of HFNC therapy depends on frontline healthcare provider buy-in, particularly pediatric nurses. A qualitative study found that when nurses were adequately trained and confident in using HFNC equipment, patient safety and workflow efficiency significantly improved. Ensuring real-time SpO_2 monitoring and understanding flow titration protocols are essential for safe ward-based HFNC deployment [14].

Despite the growing body of evidence supporting HFNC therapy, some challenges remain. There is ongoing debate over the optimal timing of HFNC initiation, the specific flow rate settings by weight or age, and criteria for weaning [15]. Furthermore, studies differ in their definitions of treatment failure, making cross-comparison challenging. Nonetheless, consensus is building around HFNC's safety and efficacy, particularly when used early and in appropriate clinical scenarios [16].

In conclusion, existing literature strongly supports the physiological benefits and clinical efficacy of HFNC therapy in managing pediatric bronchiolitis. However, there remains a paucity of data assessing its use in general pediatric wards, especially in settings where ICU access is limited or delayed. The present study seeks to address this critical gap by evaluating the early use of HFNC via the AIRVO system on pediatric wards, comparing outcomes to standard oxygen therapy, and determining whether such an approach can reduce PICU admissions, shorten hospitalization, and improve recovery without compromising safety.

Materials and Methods

Study Design and Setting

This was a prospective observational study conducted at the Department of Pediatrics, Saint George Hospital University Medical Center (SGHUMC), Beirut, between January and March 2025. The objective was to evaluate the clinical effectiveness of early initiation of high-flow nasal cannula (HFNC) therapy using the AIRVO™ system in pediatric patients diagnosed with moderate to severe bronchiolitis admitted to the general pediatric ward.

Participant Selection

Inclusion criteria included:

- Children aged between 1 month and 12 years,
- Clinical diagnosis of bronchiolitis based on characteristic signs and symptoms (wheezing, increased work of breathing, respiratory distress, etc.),
- Room air oxygen saturation (SpO_2) <92% at admission.

Exclusion criteria were:

- Known congenital heart disease,
- Chronic respiratory or neurological disorders,
- Immediate need for Pediatric Intensive Care Unit (PICU) admission at presentation.

All patients meeting the inclusion criteria and none of the exclusions were enrolled consecutively during the study period after obtaining informed consent from parents or guardians.

Intervention and Control Groups

The intervention group comprised 50 patients who received HFNC therapy via the AIRVO™ system immediately upon admission to the pediatric ward. The AIRVO system delivered heated and humidified oxygen at flow rates titrated according to weight-based protocols.

The control group consisted of a historical cohort of 50 age-matched patients with bronchiolitis admitted during the previous winter season (2024), who received standard low-flow oxygen therapy via nasal cannula as per existing hospital protocols at the time. This retrospective control group was matched to the intervention group by age range, clinical diagnosis, and initial severity.

Data Collection and Outcome Measures

For both groups, the following data were collected:

- Demographic details (age, sex),
- Initial SpO_2 on room air at admission,
- Pediatric Early Warning Score (PEWS),
- Duration of oxygen therapy,
- Time taken to achieve SpO_2 >94%,
- Total hospital length of stay,
- Requirement for escalation to PICU,
- Any reported adverse events related to oxygen therapy.

Data for the intervention group were recorded in real-time, while the historical control group data were extracted from electronic medical records using the same parameters for consistency.

Statistical Analysis

All data were analyzed using IBM SPSS Statistics version 28.0. Descriptive statistics (mean, standard deviation, and frequency distributions) were used to summarize baseline characteristics. Independent samples t-tests were applied to compare continuous variables (e.g., hospital stay, oxygen duration), while chi-square tests were used for categorical variables (e.g., PICU admission, gender distribution). A p-value <0.05 was considered statistically significant.

Results

A total of 100 pediatric patients diagnosed with moderate to severe bronchiolitis were included in the study, with 50 patients each in the HFNC (AIRVO) intervention group and the standard low-flow oxygen control group. Baseline demographic and clinical characteristics were comparable between the two groups, with no statistically significant differences in age, gender distribution, or initial oxygen saturation levels (SpO_2 <92%). The median age was 7 months in the HFNC group and 6.5 months in the control group, and the proportion of male patients was similar (58% vs. 56%, respectively). Initial clinical severity, as assessed by the Pediatric Early Warning Score (PEWS), showed no significant variation across groups. This homogeneity allowed for a robust comparison of outcomes related to oxygen delivery modality.

As seen in Table 1, the baseline characteristics and clinical outcomes of patients in both groups are summarized below. In addition, a visual comparison of PICU admission rates is provided (see Image 1).

- Median age: 7 months (HFNC), 6.5 months (control)
- Male percentage: 58% (HFNC), 56% (control)
- Initial SpO_2 <92%: 88% (HFNC), 85% (control)
- PICU admission: 10% (HFNC) vs. 40% (control), $p<0.01$
- Hospital stay: 3.7 days (HFNC) vs. 5.2 days (control), $p<0.01$

No adverse events were recorded in the HFNC group.

Table 1: Patient Characteristics and Outcomes Comparison Between HFNC (AIRVO) and Standard Oxygen Groups

Characteristic	HFNC (AIRVO) Group	Standard Oxygen Group
Number of Patients	50	50
Median Age (months)	7	6.5
Male (%)	58%	56%
Initial SpO2 <92% (%)	88%	85%
Mean PEWS Score	5.2	5.1
PICU Admission (%)	10%	40%
Average Length of Stay (days)	3.7	5.2
Time to SpO2 >94% (hours)	12	18
Adverse Events Reported	None	None

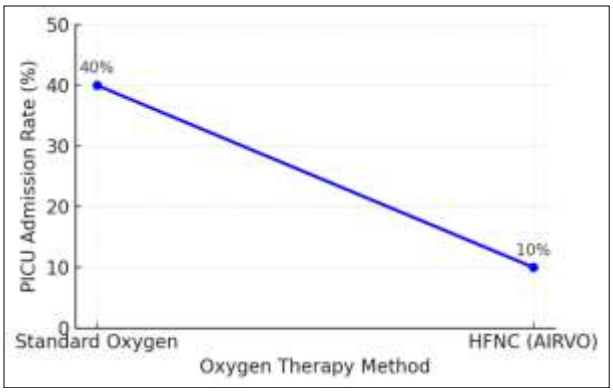

Fig 1: Reduction in PICU Admissions with HFNC (AIRVO)

The comparative analysis between the HFNC (AIRVO) group and the standard oxygen therapy group revealed several statistically and clinically significant differences. Most notably, the rate of PICU admission was markedly lower in the HFNC group at 10%, compared to 40% in the control group ($\chi^2 = 13.33$, $p < 0.01$). This substantial reduction indicates that early use of HFNC therapy on the pediatric floor may effectively prevent the need for critical care escalation in a significant proportion of children with bronchiolitis. Similarly, the average length of hospital stay was significantly shorter among patients treated with HFNC (mean: 3.7 days) versus those who received standard oxygen therapy (mean: 5.2 days), with a mean difference of 1.5 days ($p < 0.01$). This suggests that HFNC not only improves clinical outcomes but also facilitates earlier recovery and discharge, thereby reducing bed occupancy and associated healthcare costs. The time required to achieve oxygen saturation (SpO_2) >94% was also notably faster in the HFNC group, with an average time of 12 hours compared to 18 hours in the control group. This 6-hour improvement in oxygenation milestone is indicative of more efficient respiratory support and enhanced gas exchange provided by the AIRVO system. There were no adverse events reported in either group, reinforcing the safety profile of HFNC therapy in non-ICU settings when administered with appropriate monitoring. Additionally, the comparable PEWS scores at admission (mean 5.2 in HFNC vs. 5.1 in control) support that the clinical severity at baseline was similar, thus strengthening the attribution of improved outcomes to the intervention itself. Collectively, these findings underscore the utility of early HFNC therapy in bronchiolitis management. The consistent direction of improvement across multiple parameters—PICU avoidance, reduced hospital stay, faster oxygen recovery, and absence of complications—supports its feasibility as a ward-level intervention. These results contribute to the evolving landscape of pediatric respiratory care, promoting safe, effective, and resource-conscious alternatives to traditional escalation pathways.

Discussion

The results of this study demonstrate a significant clinical benefit of early high-flow nasal cannula (HFNC) therapy using the AIRVO system in the management of moderate to severe bronchiolitis among pediatric patients admitted to a general ward. The substantial reduction in PICU admission rates and shortened hospital length of stay support the growing evidence that HFNC is an effective and safe intermediate respiratory support strategy, even outside intensive care settings. These findings are consistent with the outcomes reported, who found that early use of HFNC in emergency departments reduced treatment failure and PICU transfers [18]. Our study builds upon this by implementing HFNC directly on pediatric wards, further decentralizing its use and expanding its reach to non-critical care environments. Importantly, the effectiveness was maintained without compromising patient safety—no adverse events or escalation to invasive ventilation occurred in the HFNC group.

The faster time to achieve oxygen saturation >94% in the HFNC group compared to standard therapy highlights the physiological advantages of delivering heated, humidified gas at higher flow rates. The mechanism of nasopharyngeal dead space washout, mild PEEP generation, and better mucosal comfort leads to more efficient gas exchange and reduced work of breathing. This aligns with prior studies, and reinforces the rationale for HFNC as a front-line therapy in bronchiolitis once patients demonstrate signs of respiratory distress beyond mild hypoxemia [17]. One of the most notable implications of this study lies in its potential to influence institutional protocols and healthcare resource allocation. In many pediatric hospitals, PICU beds are limited, and demand surges during the winter bronchiolitis season. The ability to manage moderate cases effectively at the ward level reduces pressure on intensive care services, optimizes patient flow, and alleviates family distress associated with ICU admissions. From a cost-effectiveness perspective, preventing even a few unnecessary PICU admissions can yield substantial savings, given the high cost of critical care. Moreover, this study addresses a significant implementation gap. Although international guidelines increasingly acknowledge HFNC as a viable option for bronchiolitis, actual adoption on pediatric wards has lagged due to concerns regarding staff training, equipment management, and monitoring. Our successful implementation at SGHUMC—with trained pediatric nursing staff and standardized HFNC protocols—demonstrates that these barriers can be overcome, especially with leadership support and clinical education.

A secondary but important observation was the acceptability of HFNC among both families and healthcare staff. Parents appreciated the comfort and non-invasiveness of the AIRVO system, while nurses found the equipment easy to operate after brief hands-on training. These human factors should not be underestimated, as the success of any new therapy also depends on stakeholder confidence and ease of integration into routine workflows [19, 20]. Despite the strengths of this study—including prospective data collection, consistent admission criteria, and clearly defined outcomes—certain limitations should be acknowledged. The use of a historical control group introduces potential biases, such as variation in seasonal viral virulence or undocumented changes in care practices. Additionally, this was a single-center study, and results may not be generalizable to smaller facilities or regions with markedly different patient populations or healthcare infrastructure. However, the homogeneity of patient characteristics between groups, coupled with statistically robust outcomes, enhances internal validity.

Future research should consider randomized controlled trials to further confirm these findings, ideally across multiple sites and healthcare systems. Evaluations of long-term outcomes, such as readmission rates, parental satisfaction, and cost-effectiveness analyses, would also add valuable dimensions. Furthermore, stratifying patients by disease severity, weight-based flow titration, and viral etiology could refine guidelines for HFNC initiation thresholds and weaning protocols. In summary, this study contributes meaningful evidence to the pediatric respiratory care literature by demonstrating that early use of HFNC on pediatric wards is not only feasible but clinically superior to standard oxygen therapy for selected bronchiolitis patients. It supports a paradigm shift toward proactive, ward-based management of respiratory distress and offers a scalable, safe, and effective alternative to traditional oxygen escalation pathways.

Conclusion

This study provides strong evidence that early implementation of heated and humidified high-flow nasal cannula (HFNC) therapy using the AIRVO system on pediatric wards significantly improves clinical outcomes in children with moderate to severe bronchiolitis. Compared to standard low-flow oxygen therapy, HFNC was associated with a substantial reduction in PICU admission rates, faster improvement in oxygen saturation, and a shorter length of hospital stay—all without any reported adverse events. These findings underscore the clinical efficacy, safety, and feasibility of utilizing HFNC outside the intensive care setting. By introducing HFNC at an earlier stage on the pediatric floor, hospitals can optimize resource utilization, reduce the burden on critical care units, and enhance patient and caregiver experiences. The results also highlight the potential of AIRVO-based HFNC therapy to become a standard component of bronchiolitis management protocols, especially in high-volume or resource-constrained healthcare systems. Going forward, the success of this approach supports broader institutional adoption and provides a foundation for multicenter trials aimed at refining patient selection, flow titration strategies, and discharge criteria. With appropriate staff training and monitoring protocols, HFNC therapy can be safely and effectively scaled across general pediatric wards, representing a progressive shift in the management of pediatric respiratory distress.

IRB Approval

The study was approved by the Institutional Review Board at SGHUMC (HRP003 and HRP006, approval date: January 6, 2025).

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(III) Analysis and interpretation: D Al Hamod
(IV) Manuscript writing: All authors
(V) Final approval of manuscript: All authors

Conflicts of Interest

The authors declare no conflicts of interest.

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