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Original Article

Paediatrics Section

Clinical Profile and Outcome of High Flow Nasal Cannula Therapy in Children with Acute Respiratory Distress: A Single Centre Retrospective Cohort Study from Southern India

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ABSTRACT

Introduction: High Flow Nasal Cannula (HFNC) therapy is being widely used as a treatment option for acute respiratory support prior to tracheal intubation or invasive ventilation. HFNC is a form of therapy in which high concentrations of oxygen, with adequate humidity and temperature, are administered non invasively via a nasal cannula. This approach has been shown to reduce airway resistance and improve lung compliance. While there are studies in Western literature regarding the efficacy of HFNC therapy in children in developed countries, there is still a paucity of data on the outcomes and efficacy of HFNC therapy in children in developing countries.

Aim: To describe the clinical profile and outcomes of HFNC therapy in children admitted to a Paediatric Intensive Care Unit (PICU) with acute respiratory distress, as well as to identify the risk factors for failure of HFNC therapy in these children.

Materials and Methods: This was a retrospective cohort study conducted by analysing the case records of children admitted with severe respiratory distress to the PICU of a tertiary care hospital in Southern India during the period from January 1, 2023, to December 31, 2023. The results were analysed over a three-month period from January 1, 2024, to March 31, 2024. In this study, 55 children aged between one month and 18 years were included if they had received HFNC therapy for acute respiratory distress during the study period. Clinical and demographic data were collected and analysed with regard to the aetiology of acute respiratory distress, the indication for HFNC therapy, and the outcome.

Results: During the study period, 55 (23.6%) of the 233 children admitted to the PICU required HFNC oxygen therapy for acute distress. Of these, 24 (43.6%) were children less than one year of age. The most common indication for HFNC therapy was bronchiolitis in acute respiratory distress (58.2%). In this study, 43 (78.2%) of the 55 children improved with HFNC; however, 12 children (21.8%) required escalation to invasive mechanical ventilation, which was considered a treatment failure. The reasons for treatment failures were analysed and found to include desaturation with worsening of the primary pathology and discontinuation of HFNC due to nasal discomfort, particularly in older children.

Conclusion: This study concluded that HFNC therapy is beneficial, offering favourable outcomes and alleviating the need for more invasive forms of ventilation.

Keywords: Bronchiolitis, High flow oxygen, Paediatric intensive care, Non invasive ventilation

INTRODUCTION

HFNC oxygen therapy was originally introduced as an alternative to Continuous Positive Airway Pressure (CPAP) therapy for preterm babies with respiratory distress. Over the years, it has been increasingly used as a form of non invasive ventilatory support in infants and children presenting with acute respiratory distress and hypoxia [1].

The basic principle of HFNC therapy is to deliver heated and humidified oxygen at high flow rates that exceed the inspiratory demand. HFNC provides positive airway pressure, which aids in the recruitment of collapsed airways and washes out upper airway dead space, leading to improved oxygenation. This process reduces hypoxia and normalises the increased work of breathing. HFNC therapy delivers a mixture of air and oxygen via tubing that sits just inside the nostrils. For hospitalised patients with respiratory distress caused by conditions such as pneumonia or airway diseases, HFNC therapy may support their breathing without the risks of lung injury associated with invasive ventilation. In adults, this therapy has significantly reduced the need for intubation and invasive ventilation [2].

There is sufficient data in the literature from developed countries regarding the use of HFNC therapy in neonates and adults with respiratory distress due to diverse aetiologies [3-5], yielding promising outcomes. Most inferences to date have primarily been derived from observations made in neonatal and adult studies [6,7]. However, there remains a lack of data concerning the efficacy and outcomes of HFNC therapy in children, especially from developing countries. Further research into HFNC therapy in children is essential, as there is a global shift in practice from invasive to non invasive modes of ventilation, like HFNC, wherever applicable. This shift aims to reduce the incidence of ventilator-associated lung injury, which is emerging as a significant challenge with invasive ventilation.

HFNC therapy has the potential to revolutionise the care of sick children with acute respiratory distress in developing countries, as this therapy is neither costly nor resource-intensive, unlike invasive ventilation. Staff can be easily trained in the application of HFNC therapy and in the care of children receiving this treatment. This study represents a single-centre experience from Southern India, highlighting the indications for the need for HFNC therapy in children with acute respiratory distress and hypoxia, as well as the outcomes of such therapy.

With this background, the present study was conducted to describe the clinical profile and outcomes of HFNC therapy in children

admitted to a PICU with acute respiratory distress and to identify the risk factors for failure of HFNC therapy in these children.

MATERIALS AND METHODS

This was a retrospective cohort study conducted by analysing the case records of children admitted to the PICU of Sree Balaji Medical College Hospital, a tertiary care teaching hospital in Southern India. The study included all children aged from one month to 18 years who were admitted between January 1, 2023, and December 31, 2023, and who had acute respiratory distress and hypoxia requiring HFNC therapy. The results were analysed over a period of three months, from January 1, 2024, to March 31, 2024. Informed written consent was obtained from the parents. This study was duly approved by the Institutional Ethics Committee of Sree Balaji Medical College Hospital (ref no. 002/SMCH/IHEC/2022/1756).

Inclusion criteria: Children aged from one month to 18 years with acute respiratory distress and hypoxia who required HFNC support for any duration during that admission within the study period were included in the study.

Exclusion criteria: Children less than one month or more than 18 years with acute respiratory distress who did not require high-flow oxygen and those with respiratory failure who required invasive mechanical ventilation were excluded from the study.

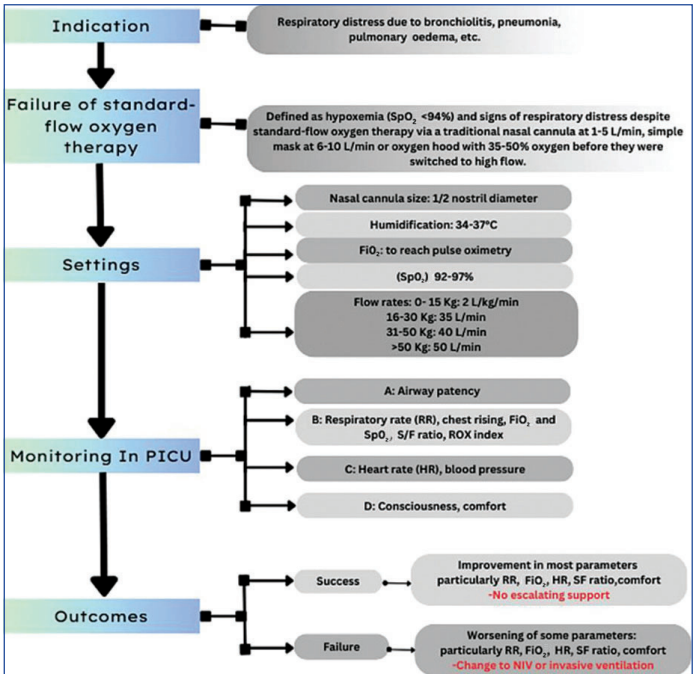
Acute respiratory distress was defined as [4]:

a) Hypoxia with SpO_2 <92% despite standard flow oxygen therapy administered either via a traditional nasal cannula at 1 to 5 L/min, a simple face mask at 6 to 10 L/min, or an oxyhood with 35-50% FiO_2;

b) Physical signs of respiratory distress, such as:

- Increased Respiratory Rate (RR) according to age (up to 1 year: RR > 50; 1 to 5 years: RR > 40; beyond 5 years: RR > 30);
- Increased work of breathing, including intercostal and subcostal retractions, nasal flaring, grunting, cyanosis and wheezing.

An institutional protocol [Table/Fig-1] for HFNC therapy in children, adapted from a study conducted by Chang CC et al., in Taiwan, was used in the study. This protocol included guidelines for HFNC settings, monitoring and outcomes [4].



[Table/Fig-1]: Protocol for HFNC therapy.
NIV: Non invasive ventilation

HFNC was delivered using the Optiflow System (Fisher and Paykel). FiO_2 was adjusted to achieve target oxygen saturation levels, as measured by pulse oximetry, between 92% and 97%. The oxygen flow rate setting was determined based on the patient's body weight and the nature of the disease for which the therapy was initiated. All vital parameters, including heart rate, RR, and pulse oximetry readings, were monitored, and the ratio of SpO_2/FiO_2 to respiratory rate (ROX) index was calculated at the initiation and discontinuation of HFNC therapy.

Escalation to mechanical ventilation was considered a failure of HFNC treatment. Using a standard proforma, the following details were collected for all patients: demographics such as age, sex, primary indication for HFNC and clinical parameters of disease severity, which included RR, heart rate and pulse oximetry readings. HFNC settings, including FiO_2 and flow rate, were also recorded. Descriptive statistics were used to describe the demographics and HFNC utilisation data.

The outcome was recorded as a failure if there was an escalation to invasive mechanical ventilation at any point during therapy. The ROX index score [8], defined as the ratio of oxygen saturation (measured by pulse oximetry) to RR, was recorded at the initiation and at 12-24 hours of HFNC therapy. The ROX index was first devised during the Coronavirus Disease 2019 (COVID-19) crisis to predict HFNC failure or the need for intubation. HFNC failure was defined as the need for escalation to non invasive ventilation or invasive mechanical ventilation. The decision to escalate treatment was made by the treating intensive care physician, typically occurring if FiO_2 > 0.6 or if there was a worsening clinical state [9]. The treatment was deemed a success if the child recovered without any escalation to invasive mechanical ventilation.

STATISTICAL ANALYSIS

The data gathered was analysed using Statistical Package for the Social Sciences (SPSS) Statistical software version 20.0.

RESULTS

During the study period, 55 (23.6%) children out of the total 233 admitted to the PICU satisfied the inclusion criteria and were initiated on HFNC oxygen therapy for acute respiratory distress. The most common indication for the use of high-flow nasal cannula oxygen therapy was severe bronchiolitis, with 32 cases (58.2%), followed by pneumonia in 17 cases (30.9%), and other conditions such as congenital heart disease in Congestive Cardiac Failure (CCF), ARDS due to sepsis, and acute severe asthma, accounting for 6 cases (10.9%). It was observed that 43 (78.2%) of the 55 children improved with HFNC; however, 12 children (21.9%) required escalation to invasive mechanical ventilation, which was considered treatment failure [Table/Fig-2].

Parameter	n=55 (%)	Success=43 (78.2%)	Failure=12 (21.8%) (Mechanical ventilation)
Age			
1month- 1 year	24 (43.6)	20 (46.5)	4 (33.3)
>1-5 years	21 (38.2)	16 (37.2)	5 (41.7)
>5-18 years	10 (18.2)	7 (16.3)	3 (25.0)
Sex			
Boys	27 (49)	20 (46.5)	7 (58.3)
Girls	28 (51)	23 (53.5)	5 (41.7)
Medical history			
Previously healthy	45 (81.8)	39 (90.7)	6 (50.0)
Neurological disorder (CP, Epilepsy)	3 (5.5)	1 (2.3)	2 (16.7)
Asthma	1 (1.8)	1 (2.3)	0
Lung disorder (BPD)	4 (7.3)	1 (2.3)	3 (25.0)
Others (CHD)	2 (3.6)	1 (2.3)	1 (8.3)
Indication for HFNC			
Bronchiolitis	32 (58.2)	30 (69.8)	2 (16.7)
Pneumonia	17 (30.9)	11 (25.6)	6 (50.0)
Others	6 (10.9)	2 (4.6)	4 (33.3)

[Table/Fig-2]: Demographic parameters of the study population.

The reasons for treatment failures were analysed and found to include desaturation with worsening of primary pathology in seven cases (12.7%) and discontinuation due to nasal discomfort, particularly in older children, in five cases (9.09%). It was also noted that the failure group had significantly higher initial flow rates and FiO_2 levels than the success group. The ROX index score is a simple bedside index calculated using SpO_2, RR, and FiO_2, which helps predict the success and failure of HFNC therapy. Present found that higher ROX index values (>4.1) at 12 hours on HFNC therapy were associated with high success rates [Table/Fig-3].

Parameter	n=55 (%)	Success=43 (78.2%)	Failure=12 (21.8%)
Initial HFNC settings (mean)			
Flow (l/min)	30.13±1.75	28.21±1.65	37.12±1.61
FiO_2 (%)	45.92±10.71	43.21±8.51	60.43±15.62
Maximum HFNC settings (mean)			
Flow (l/min)	55±5.12	53±4.22	65±7.16
FiO_2 (%)	60±4.12	57±2.12	82±10.15
ROX index at the start of HFNC therapy			
>3.5	12 (21.8)	24 (55.8)	9 (75.1)
<3.5	43 (78.2)	19 (44.2)	3 (24.9)
ROX index at 12 hours of HFNC therapy (n=55)			
>4.1	48 (87.3)	48 (87.3)	-
<4.1	7 (12.7)	-	7 (12.7)
Outcome of HFNC therapy	-	43 (78.2)	12 (21.8)

[Table/Fig-3]: Clinical parameters of the study population.

With the increase in the duration of HFNC therapy, heart rate, RR, and SpO_2 levels improved from baseline to 12-24 hours of therapy [Table/Fig-4].

Parameter	Baseline average (Before HFNC)	Early HFNC <6 hours	Late HFNC 12-24 hours
Heart rate	130 (114-146)	118 (100-136)	109 (98-120)
Respiratory Rate (RR)	52 (34-68)	38 (30-46)	33 (22-44)
SpO_2	88 (86-92)	95 (90-99)	99 (95-99)
Arterial Blood Gas (ABG)			
pH	7.32 (7.35-7.46)	7.36 (7.35-7.44)	7.38 (7.35-7.45)
pCO_2	40.3 (30-45.1)	41.1 (38.1-42.3)	42 (30.1-43)

[Table/Fig-4]: Comparison of clinical parameter at different time points of HFNC.

DISCUSSION

HFNC therapy was traditionally used in neonates. However, it has been expanded to include children and adults across all causes of acute hypoxemic respiratory failure, especially bronchiolitis. HFNC therapy is now widely utilised, starting from the Emergency Department (ED) to the PICU. It delivers high flow rates of heated air/oxygen breathing mixtures in an open system at the preset fraction of inspired oxygen concentration [10,11]. The high flow rates produce a washout of the anatomic dead space and augment effective alveolar ventilation, thereby improving SpO_2 levels and helping to reduce Partial Arterial Pressure of Carbon Dioxide ($PaCO_2$) levels [12]. It also produces a minimum Positive End-Expiratory Pressure (PEEP), which is especially helpful in keeping unstable alveoli open, recruiting alveoli and increasing functional residual capacity. Additionally, it reduces respiratory resistance and the high work of breathing, which is a common feature in patients with respiratory failure [13,14]. Its most important characteristics include ease of implementation and good patient tolerance, making it a promising mode of support that has been continuously expanding over the last decade.

In this retrospective study conducted from January to December 2023, clinical profile of children of all ages admitted to a tertiary care paediatric ICU in Southern India, presenting with acute respiratory distress and hypoxia who underwent HFNC therapy was studied. The study analysed the outcomes of HFNC therapy in such children, particularly regarding the percentage of children who recovered on HFNC without escalation to invasive ventilation. Study also identified some potential risk factors for the failure of HFNC therapy. It was observed that nearly 23.6% of the children admitted with acute respiratory distress during the study period were initiated on HFNC therapy as the first line of treatment, which was consistent with the findings of Wraight TI and Ganu SS, who reported 33%. The percentages of boys and girls were nearly equal [13]. The most common indication for HFNC therapy in present study was bronchiolitis; however, observations made by Chang CC et al., from Taiwan indicated that pneumonia was the most common indication [4]. This discrepancy may be attributed to regional differences in disease aetiology.

A total of 78.2% of children in the present study recovered on HFNC without a need for escalation of therapy, similar to findings by Coletti KD et al., [15]. The failure rate in present study was 21.8%. It was observed that children requiring higher flow rates, higher FiO_2 at initiation, and those with a ROX index score of less than 4.1 at 12 hours of therapy required escalation to invasive ventilation. A study by Mayfield S et al., also reported an 8% failure rate for HFNC therapy in children [16]. This study had diverse aetiologies, similar to the observations made by Baudin F et al., [17]. Notably, present study did not observe any complications due to HFNC therapy, such as epistaxis or air leaks, unlike those reported in studies by Baudin F et al., and Kelly GS et al., [17,18].

Limitation(s)

This was a retrospective study utilising existing clinical data. Although this method is relatively quick and inexpensive, the analysis was conducted solely on data that was already available. Consequently, this can be less accurate than the results obtained from a prospective study. Therefore, prospective studies, preferably multicentre, are needed to further confirm the efficacy of HFNC therapy in children and to evaluate the risk factors for failure in different settings.

CONCLUSION(S)

HFNC oxygen therapy is a relatively new form of non invasive ventilatory support that is increasingly used in children presenting with acute respiratory distress and hypoxia. This therapy has significantly reduced the need for intubation and invasive ventilation. Present study showed that HFNC therapy is promising, with relatively good outcomes in children presenting with acute respiratory distress and hypoxia, thereby reducing the need for invasive ventilation modalities. HFNC was effective in preventing intubation in more than 78% of the children with acute respiratory distress in the study, with relatively low failure rates. This study observed that HFNC could maintain low failure rates if it is initiated for the right patient and at the right time. A ROX index score greater than 4.1 at 12 hours of HFNC therapy predicts a favourable outcome. In conclusion, HFNC is an effective and safe primary mode of respiratory support in children with respiratory distress due to various causes. However, this was only a single-centre experience. Larger multicentre studies are required to standardise treatment protocols regarding HFNC therapy in children to optimise outcomes.

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