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Exploring the effectiveness of high-flow nasal cannula in the neurointensive care unit: a prospective observational study

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Abstract

Background Acute respiratory failure is common occurrence in critical care, with varying causes, depending on case mix of the ICU. High flow nasal cannula (HFNC) is commonly utilized in both adult and pediatric population. However, traditionally, neurologically ill patients have been considered unsuitable for HFNC due to poor sensorium and risk of aspiration. Therefore, we conducted a study to assess the effectiveness of HFNC in Neuro ICU.

Methodology We did a prospective observational study on all adult patients requiring HFNC during their stay in Neuro ICU. Primary aim of the study was to find common indications for use of HFNC in neuro ICU. The secondary objective was to observe if HFNC could prevent re-intubation. The various other factors studied included age, gender, diagnosis (traumatic brain injury, postoperative neurosurgical condition or other neurological conditions), GCS score, HFNC settings, duration and cost of HFNC therapy.

Results During the period from January 1, 2021- 23, out of 1825 patients admitted to neuro ICU, 98 required HFNC therapy. Mean age was 43.3 years (range 18–85), 75.5% of which were males. Utilization rate of HFNC was 5.3%. HFNC was more commonly used for non-trauma patients, most often to reduce work of breathing following extubation (85%). HFNC helped prevent the need for re-intubation in 76.5% of patients with a failure rate of 23.5% across all subgroups of patients in neuro ICU. Requirements for higher flow rate and FiO_2 were significant predictors of HFNC failure. The mean cost of HFNC usage accounted for only 5.6% of the total inpatient bill.

Conclusion In neurocritical care, the causes of extubation failures and hypoxemia, differ significantly from other ICUs. In our study, HFNC was used most often to reduce work of breathing following extubation and was useful in preventing re-intubation. The use of HFNC did not significantly increase the cost of healthcare.

Keywords High flow nasal cannula, Weaning, Neurocritical care, Non- trauma, Cost of health care

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Introduction

The efficacy of high-flow nasal cannula (HFNC) in the management of acute respiratory failure has been well established. The multicenter randomized Florali trial [1] demonstrated reduction in 90-day mortality with the use of HFNC in comparison to standard oxygen therapy. HFNC has exhibited sustained improvement in both clinical and biological parameters. On average, 27.6 h of HFNC usage resulted in an increase in partial pressure of oxygen (PaO_2) from 87.3 to 158.0 mm Hg, with mild elevation in partial pressure of carbon dioxide ($PaCO_2$), that did not impact pH [2]. Physiological effects of HFNC include the elimination of CO_2 in anatomical dead space, overcoming expiratory resistance and providing positive end-expiratory pressure (PEEP), facilitating the opening of atelectatic alveoli, consistent delivery of FiO_2, and the supply of warmed and fully humidified air to maintain mucociliary function, thereby enhancing patient comfort.

The use of this device is not recommended for patients who are poorly conscious, suffer from claustrophobia, have airway obstruction, facial injury or malformation, are at risk of aspiration, have unstable hemodynamics, or have experienced respiratory arrest.

The use of HFNC therapy has gained extensive acceptance in both adult and pediatric critical care settings. However, it is pertinent to note that the existing trials validating its benefits have notably involved limited participation from neurologically ill patients. For instance, the Florali trial included 7% of neurocritical patients only [1]. Given the diverse etiologies of respiratory failure in this subset, such as bulbar weakness, impaired cough and gag reflexes, the applicability of HFNC remains uncertain. Nevertheless, Lobato et al., have documented successful treatment of hypercapnic respiratory failure in a patient with amyotrophic lateral sclerosis using HFNC [3]. Building on this, we conducted this observational study with specific aim to evaluate the indications for usage of HFNC in Neuro ICU.

Methodology

This descriptive observational study was conducted in the neurocritical care department of a tertiary care center in south India. This study was approved by the institutional review board with a waiver of consent (IRB Min No: 14383 dated 22.12.2021) in accordance with the Declaration of Helsinki.

The primary outcome of interest was to identify common reasons for use of HFNC in Neurologically ill patients. The secondary outcome of interest was to observe if use of HFNC could prevent the need for invasive mechanical ventilation. Additionally, we compared the cost of use of HFNC with the overall hospitalization cost also, as secondary outcome of interest.

The study's eligibility criteria encompassed adult patients admitted to the neuro ICU where HFNC was utilized. Indications for HFNC usage included correction of hypoxemia, hypercarbia, reduction of increased work of breathing (respiratory rate > 25/min and use of accessory muscles), alleviation of post extubation stridor or upper airway obstruction relieved by positioning and not requiring emergency intubation. The decision to initiate HFNC was taken by a single physician (SN) in all the cases which helped reduce bias. Patients below 18 years and those for whom HFNC was contraindicated were excluded.

The Airvo 2 (Fisher & Paykel Healthcare Ltd., Auckland, NZ) was utilized to administer high-flow nasal oxygen. The device was set with a flow setting between 30 and 60 L /min and FiO2 was adjusted based on the patient's oxygenation status from pulse-oximetry or arterial blood gas samples. The successful application of HFNC therapy was evidenced by the patients' transition to venturi or face mask. The necessity for intubation or tracheostomy was deemed as HFNC failure. Blood gas analysis after 30 min of HFNC application along with clinical assessment provided an early likelihood of failure and need for intubation. A repeat analysis was done by 2 h to confirm improvement in respiratory status.

Desaturation, increasing work of breathing or drop in GCS were considered clinical cue along with the ABG to consider HFNC to have failed.

Variables studied included demographic information, the rationale for HFNC use, duration of utilization and the outcomes of HFNC therapy. Outcome variables comprised de-escalation to facemask/venturi, reintubation, tracheostomy, necessity for positive pressure ventilation, instances of respiratory arrest, and mortality. Additionally, an analysis of the percentage of the total hospital bill attributable to HFNC use was conducted to assess the economic implications of usage of the device. The cost of HFNC was accredited based on FiO_2 usage for each hour. This was compared against the total hospital bill.

Statistical analysis

Statistical analysis was performed using IBM SPSS statistics 27.0 (SPSS, Chicago, USA). Continuous variables were expressed as the means + standard deviation (SD). Categorical variables were presented as the frequency (n) and percentages (%) and were compared using chi-squared test or Fisher's exact test. Nonparametric data were compared using Wilcoxon Rank- sum test. $P < 0.05$ was considered statistically significant. Based on a pilot study conducted in the department, 5.1% of patients required HFNC. With this background data, expecting a 1% precision and 95% desired confidence level, the sample size was calculated to be 1825 patients admitted in Neuro ICU.

Results

During the period from January 1st, 2021, to January 1st, 2023, 98 out of 1825 inpatients in the Neuro ICU necessitated the use of HFNC therapy, resulting in a utilization rate of 5.3% (Fig. 1). The patient demographic spanned an age range from 18 to 85 years, with a mean age of 43.3 years. The study cohort primarily comprised male individuals at a ratio of 3:1 (Table 1).

HFNC therapy was administered to patients admitted in Neuro ICU, including those with traumatic brain injury, neurological emergencies, and postoperative neurosurgery. It was predominantly used for post-extubation patients, except one neuromuscular patient for whom it was used pre-intubation. HFNC therapy was more frequently employed for non-trauma patients ($n=57$) compared to trauma patients ($n=41$). Among the 31 neurosurgical patients in whom HFNC was used, six experienced failures, resulting in 19% failure rate. For neurological patients, HFNC was utilized in 26 cases, with 7 instances of failure, equating to 27% failure rate.

Notably, the most common reason for HFNC usage was increased work of breathing (85%) following extubation. The other indications for use of HFNC were stridor (10%), hypoxemia (4%) and hypercapnia (2%) (Table 1). Lower GCS score (< 8) at admission was found to be statistically significant among patients who failed HFNC. Initial HFNC initiation involved higher flow rates averaging 54 L/min and a relatively lower FiO2 of 0.5, which were significantly reduced within 2 to 8 h of initiation (Fig. 2).

The median duration of HFNC usage was 2 days. HFNC was successful in 76.5% of patients, effectively preventing intubation. Successful use of HFNC helped to wean to a face mask in 57.3% ($n=43$) compared to only 5.3% ($n=4$) needing venturi. Patients who required intubation following HFNC failure were relatively older and had lower Glasgow Coma Scale (GCS) scores. An initial high flow setting and need for increasing flow rates were also associated with HFNC failure. However, irrespective of initial FiO_2 requirement, a serial increase in FiO_2 was a significant predictor of HFNC failure (Table 1). The reasons for HFNC failure varied from increased work of breathing ($n=10$, 43%) to desaturation ($n=8$, 35%) and drop in GCS score ($n=5$, 22%). Prompt decisions regarding intubation or tracheostomy, resulting in a shorter HFNC duration for these patients were observed in comparison to those de-escalated to face mask (1 Vs 2 days).

The average cost of HFNC usage accounted for only 5.6% of the total hospitalization cost. The proportional cost of usage increased with the duration of use, as evidenced by a higher cost among patients who could be de-escalated to face mask. This underscores the recognition

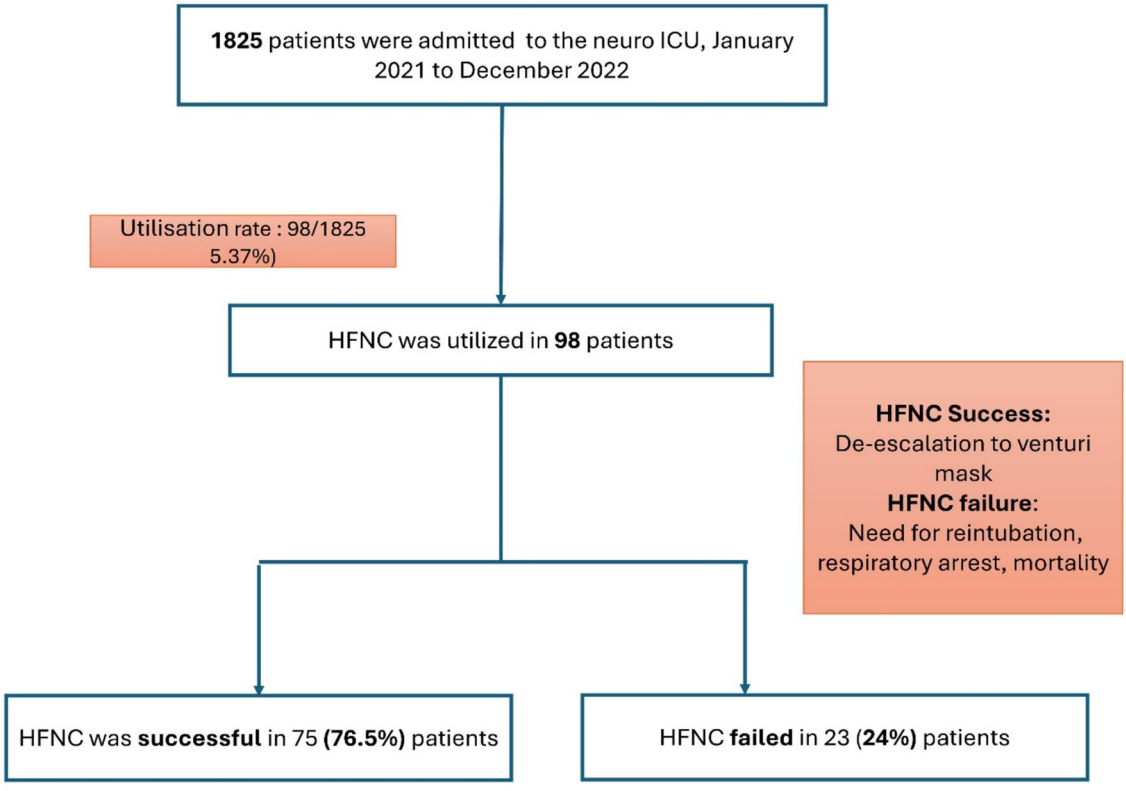

Fig. 1 Strobe figure

Table 1 Summary and comparison of study variables between patient groups

Characteristic	Total (*n* = 98)	HFNC Success (*n* = 75)	HFNC Failure (*n* = 23)	*p* Value **
Age (years), mean (SD)	43.3 (17.9)	41.4 (18.3)	49.7 (15.4)	**0.05**
Male, n (%)	74 (75.5)	55 (73.3)	19 (82.6)	
Female, n (%)	22 (24.5)	20 (26.7)	4 (17.4)	0.42
Diagnosis, n(%)				
Traumatic Brain injury	41 (41.8)	31 (41.3)	10 (43.5)	
Non-Traumatic Brain injury	57 (58.2)	44 (58.7)	13 (56.5)	0.52
Neurological emergencies	26 (45.6)	19 (43.2)	7 (53.8)	
Post operative neurosurgery	31 (54.4)	25 (56.8)	6 (46.2)	
Indication for HFNC, n(%)				0.48
Increased work of breathing	82 (83.7)	64 (85.3)	18 (78.3)	
Stridor	10 (10.2)	5 (6.7)	5 (21.7)	
Hypoxemic respiratory failure	4 (4.1)	4 (5.3)		
Hypercapnic respiratory failure	2 (2)	2 (2.7)		
GCS score, mean (SD)	11.1 (2.9)	11.4 (2.71)	10 (3.35)	0.08
Mild (12–15), n(%)	35 (36)	29 (38.7)	6 (26.1)	
Moderate (8–11), n(%)	41 (42)	34 (45.3)	7 (30.4)	
Severe (3–7), n(%)	22 (22)	12 (16)	10 (43.5)	**0.02**
HFNC Settings, mean (SD)				
Initial Flow setting - litres/min	54 (10.4)	53.6 (4)	55.2 (8.5)	0.21
First Flow change -litres/min	43.6 (10.4)	43 (10.3)	47.5 (10.6)	**0.01**
Second Flow change – litres/min	39 (9.4)	37.8(8)	60	**< 0.001**
Initial FiO2 setting	0.49 (0.13)	0.38 (0.08)	0.52 (0.13)	0.52
First FiO2 change	0.4 (0.09)	0.48 (0.12)	0.48 (0.11)	0.16
Second FiO2 change	0.34 (0.06)	0.34 (0.08)	0.4	**0.01**
HFNC utilisation, days *	2 (1, 2)	2 (1, 2)	1 (1, 2)	
Total Cost, Rupees in lacs *	3.5 (2, 5.5)	2.5 (1.6, 4.4)	5.4 (3.5, 7.4)	**0.02**
Percent cost of HFNC, mean(SD)	5.6 (3.9)	6.2 (4.2)	4 (2.4)	0.21

GCS- Glassgow coma Scale, FiO2 – Fraction of inspired oxygen, HFNC-High flow nasal canula

*values are reported as median (Interquartile range)

** p values < 0.05 was considered significant

of HFNC failure at an early stage and emphasizes the importance of avoiding unnecessary prolongation of HFNC.

Discussion

European Respiratory Society recognizes the preference for using HFNC over conventional oxygen therapy in postoperative patients at low risk of respiratory

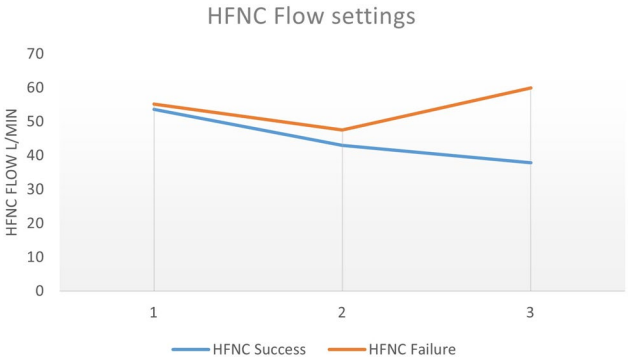

Fig. 2 Flow settings at baseline, and subsequent changes between successful and failed high flow nasal cannula patients. 1- Baseline; 2-First change; 3.-Second change

complications. Additionally, HFNC is considered an alternative to non-invasive ventilation (NIV) for high-risk patients. It is important to note that the patients mentioned above mainly pertain to cardiothoracic cases with no specific inclusion of neurosurgical patients [4]. In our prospective study focusing exclusively on critically ill neurological patients, we observed that HFNC was an useful adjunct to prevent re-intubation in both hypoxemic and hypercapnic individuals. Notably, the use of HFNC did not result in intubation delay or increased mortality in the cohort. Furthermore, the average duration of HFNC use was only 1.9 days, constituting a mere 5.6% of the total hospital cost.

In their retrospective evaluation, Wang et al., assessed the efficacy of HFNC therapy in preventing pulmonary complications in neurologically ill patients [5]. Their findings aligned with our prospective study, demonstrating a decreased requirement for invasive ventilation in patients receiving HFNC. The use of HFNC was also associated with reduced sputum viscosity and improved short-term neurological outcomes, although no significant correlation was observed with the incidence of pneumonia during hospitalization [5].

In a study by Hernandez et al., it was observed that the application of HFNC in 14 patients resulted in the prevention of one reintubation. The study group comprised a significant number of neurologically ill patients, yet the incidence of adverse outcomes was relatively low, attributed in part to a pragmatic approach of reintubation within 24 h of HFNC use following extubation [6]. Our study employed a similar methodology, closely monitoring the work of breathing and implementing a protocol to terminate the HFNC trial for re-intubation within thirty minutes of initiation. This approach not only minimized adverse events but also yielded cost savings in therapy. The cost of therapy was markedly higher in successful HFNC trials due to an extended duration of therapy.

Among the diverse array of complications following extubation, it was observed that HFNC therapy

predominantly reduced work of breathing. This resulted in a 74.0% reduction in re-intubation rates among our patients (with one exception being a patient with neuromuscular disease who received HFNC prior to intubation). The favorable impact of HFNC therapy was promptly discernible within the initial 30 min, effectively circumventing the necessity for re-intubation, and noticeably enhancing gas exchange as evidenced by arterial blood gas analysis within the first 2 h. This notable benefit can be attributed to the possible mechanism of humidifying and conditioning inspired gas, thereby facilitating the management of secretions.

Impaired cough and gag reflexes leading to aspiration and respiratory complications represent the primary non-neurological cause of deterioration of patients in the neuro ICU. In a survey by Besneir et al., assessing the clinical practice of HFNC use in ICUs, it was noted that physicians were more confident in using HFNC for hypoxemic rather than hypercapneic indications [7]. Only 44% of respondents believed in using HFNC for post-extubation acute respiratory failure. The prevalent practice was to initiate HFNC with 100% FiO_2 and a low flow rate to be gradually escalated, with only 23% of respondents practicing initiating HFNC with a high flow rate [7]. However, our practice of initiating HFNC with high flow rates from the outset has proven crucial in reducing the work of breathing. Our experience contrasts with the survey findings, as we have achieved similar success with HFNC in both hypoxemic and hypercapnic patients.

There is limited research evaluating the efficacy of HFNC in a specific neurological patient cohort. Our study identified a higher utilization of HFNC in patients without traumatic brain injury. HFNC has recently garnered recognition for managing pneumocephalus in neurosurgical patients [8, 9]. Additionally, Gook et al., effectively utilized HFNC and oxygen reserve index monitoring to prevent oxygen desaturation during an awake craniotomy [10]. In our study, among 28 neurosurgical patients receiving HFNC post-extubation, only 6 required reintubation.

In a study conducted by Lionello et al., the safety profile of HFNC was investigated in a patient cohort with neuromuscular disease who was unable to tolerate NIV [11]. The study revealed that the combination of daytime HFNC with NIV was a safe treatment approach for neuromuscular disease patients, if there was close monitoring of $PaCO_2$. Among the patients requiring HFNC in our neurological cohort, only one case of neuromuscular involvement was identified, and the device was used successfully as a primary intervention, preventing the need for intubation. Of the remaining 25 patients, 5 required reintubation, resulting in a failure rate of 20%. Significantly, there were no discernible differences in the failure rates of HFNC use between neurosurgical and neurological groups.

The utilization of HFNC proved to be cost-effective, constituting only 5.6% of the total expenses, primarily owing to its short-term usage, averaging 2 days. Data obtained from the NHS indicates that when employed as the initial treatment, HFNC demonstrates potential cost savings of £469 per patient in comparison to standard oxygen, and £611 in contrast to NIV. In contrast, in the high-severity sub-group, the cost savings associated with HFNC were £727 compared to standard oxygen, and £1,011 versus NIV [12]. However, the utilization of HFNC in the pediatric population for bronchiolitis in both low- and high-income countries was found to be linked with increased resource consumption [13, 14].

There are several limitations to our findings. As the study being an observational one in design, we cannot affirm the benefit of HFNC in reducing or preventing need for reintubation. A robust well-designed study will need to be undertaken to confirm this finding. The indications for initiating HFNC as well as to consider it to have failed, has multifactorial etiology especially in Neuro ICU. Though there was only one physician involved in such decision making, reducing the bias in this study, more objective criteria will make the findings reproducible. As this series specifically focuses on patients with neurological conditions, it is important to note that the findings may not be broadly applicable to all patients within the ICU setting. Patients with conditions such as diaphragmatic palsy, bulbar involvement, and impaired gag and cough reflexes stemming from IXth and Xth cranial nerve impairment may not be suitable candidates for HFNC therapy. Consequently, within the neurological ICU, early tracheostomy is more frequently employed compared to other critical care groups. Hence, careful selection of patients for HFNC therapy is critical to the success of this treatment approach.

Conclusion

The high-flow nasal cannula is becoming increasingly prevalent in both adult and pediatric general intensive care. Despite limited reporting in neurocritical care, we have successfully utilized HFNC in our cohort of neurological, neurosurgical, and neurotrauma patients without significantly inflating the cost of treatment. HFNC may be a valuable adjunct for preventing re-intubation in patients with neurological diseases, though a larger and better designed study may confirm such a benefit.

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Nil.

Author contributions
SN, RM, MJ and RK conceptualised the project, SN and RM collected data, data was analyzed by MJ and RK. Manuscript was written by SN, RM and RK, reviewed by MJ and RK.

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Data availability
The data will be shared on reasonable request to the corresponding author.

Declarations

Human ethics and consent to participate
Ethical clearance for the study was obtained from the institutional review board of Christian Medical College Vellore with a waiver of consent (IRB Min No: 14383 dated 22.12.2021) for the study titled "Exploring the effectiveness of High-Flow Nasal Cannula in the Neurointensive Care Unit: A prospective observational study" in accordance with the Institute's ethical standards on human experimentation and with the Helsinki declaration of 1975.

Consent to participate
Was waived by the Institutional review board as there was no change in existing practice of management.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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