

# Outcomes of a Respiratory Therapist Driven High Flow Nasal Cannula Management Protocol for Pediatric Critical Asthma Patients

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## Abstract

**Introduction:** This study aimed to determine if a respiratory therapist (RT)-driven high flow nasal cannula (HFNC) protocol could decrease duration of HFNC use, pediatric intensive care unit (PICU) and hospital length of stay (LOS), and duration of continuous albuterol use in pediatric patients with critical asthma. **Methods:** This was a quality improvement project performed at a quaternary academic PICU. Patients admitted to the PICU between 2 and 18 years of age with a diagnosis of asthma requiring continuous albuterol and HFNC were included. Implementation of a RT-driven HFNC protocol [Plan-Do-Study-Act (PDSA) 1] occurred in October 2017. Additional interventions included weaning continuous albuterol and HFNC simultaneously (PDSA 2; March 2019), adjusting HFNC wean rate (PDSA 3; July 2020), and a HFNC holiday (PDSA 4; October 2021). HFNC duration was the primary outcome. Secondary outcomes included LOS data and continuous albuterol duration. Noninvasive ventilation (NIV), invasive mechanical ventilation (IMV), and 7-day PICU and hospital readmission rates were balancing measures. **Results:** 410 patients were included. Patient demographics and adjunct therapy use did not differ among the groups. HFNC duration decreased from 26.8 to 18.1 hours, both PICU and hospital LOS were decreased (41 to 31.8 hours, and 86.5 to 68 hours respectively) after PDSA 2. These outcomes remained stable during PDSA 3 and 4. Continuous albuterol duration and NIV use remained stable, while IMV use decreased throughout the study. **Conclusions:** An RT-driven HFNC protocol led to an improvement in clinical outcomes for pediatric patients with critical asthma without an increase in adverse events.

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### *Introduction*

In 2021, the Centers for Disease Control and Prevention estimated that approximately 8.1% of children in the United States have an active diagnosis of asthma (1), which is nearly six million children. Approximately 17.9% of these children present to an urgent care or emergency room annually for acute care (1), many of which result in hospital admissions. Critical asthma is a leading diagnosis in the pediatric intensive care unit (PICU) (2,3). Hospital cost for pediatric asthma is substantially increased when a patient requires PICU level care (4,5). High flow nasal cannula (HFNC) is a respiratory support modality that allows for higher flows of oxygen via heating and humidification of the inspired gas compared to conventional oxygen therapy. It is used in a variety of respiratory diseases, including critical asthma (6). There is concern that widespread adoption of HFNC in other respiratory disease processes has contributed to increased PICU admission rates and healthcare costs (7,8). This has prompted discussions regarding more judicious use of HFNC(9).

HFNC management protocols have been shown to decrease duration of HFNC use, PICU length of stay (LOS), and hospital LOS in pediatric patients with bronchiolitis (10-13). In addition, RT-driven continuous albuterol weaning protocols have been shown to be beneficial in pediatric patients with critical asthma in the PICU (14-17). Standardization of care has been repeatedly shown to improve outcomes in the hospital setting (18,19). The aim of this quality improvement project was to determine if a HFNC management protocol and subsequent modifications could decrease the HFNC duration HFNC, PICU and hospital LOS, and continuous albuterol duration in pediatric patients with critical asthma.

### *Methods*

## Settings and Subject Population:

This quality improvement study was conducted at Riley Hospital for Children at Indiana University Health in Indianapolis, Indiana. It is a 42-bed multidisciplinary medical-surgical quaternary academic unit with approximately 2,600 admissions per year. HFNC by Fisher and Paykel Healthcare (Optiflow, Auckland, New Zealand) was used in our PICU. At our institution, HFNC is used exclusively in the PICU; patients are transferred to the general pediatric ward after they are weaned to conventional oxygen therapy. The study was reviewed and granted exemption by the Indiana University institutional review board (IRB #16163) as a quality improvement project. The HFNC protocol was used in all patients in the PICU requiring HFNC during the study period. For this analysis, we included subjects between 2 and 18 years of age with a diagnosis of critical asthma using Virtual PICU Systems (VPS) STAR codes receiving both HFNC support and continuous albuterol. We defined HFNC as use of the Optiflow device with minimum of either  $[?]1$  L/kg/min for patients weighing up to 10 kg and  $[?] 10$  L/min for patients above 10 kg (20).

## PDSA cycles 1-4

The original HFNC management protocol (PDSA 1) (supplement figure 1) was implemented in October 2017, and it allowed the RT to make decisions regarding the escalation and weaning of HFNC. Exclusion criteria at the beginning included patients requiring nitric oxide, heliox, and continuous albuterol. Prior to this, these decisions were made by the physician or advanced practice provider.

The protocol was continuously re-evaluated throughout this study. Key stakeholders met and hypothesized that continuous albuterol and HFNC could potentially be weaned together. A continuous albuterol weaning protocol had already been implemented in 2016 (supplement figure 2) based on the Pediatric Asthma Severity Score (PASS). In March 2019, a modified version of the HFNC management protocol was implemented (PDSA 2) that allowed simultaneous albuterol and HFNC weaning. We included PDSA 1 as described above since there was likely early adoption in including patients on continuous albuterol.

In July 2020, two modifications of the HFNC management protocol were implemented for patients 13 years and older (PDSA 3)(Supplement figure 3). First, it allowed for an increase in the wean increment from 2 liters per minute to 5 liters per minute. Second, it changed the point at which one could switch to simple nasal cannula from 4 liters per minute to 10 liters per minute.

Key stakeholders, including pediatric intensivists, PICU RTs and information technology specialists met again in May 2021 to re-evaluate the existing protocol and discuss further interventions to decrease length of HFNC and ultimately length of PICU and hospital LOS (supplement figure 4). Given the success of another study (13), the HFNC holiday (PDSA 4) was added as a modification to the existing protocol (Figure 1). Re-education of the RTs occurred and the HFNC holiday was implemented in October 2021. Adjustments to the EMR coincided to reflect these changes to allow the RT to chart appropriately.

## Protocol Education

RTs were given 2 months to complete education on the initial HFNC protocol and subsequent changes. Education for the initial protocol was completed between August and October 2017. Education regarding the ability to simultaneously wean continuous albuterol and HFNC was done between January and March 2019; for the change in flow weaning rate between May and July 2020, and for the HFNC holiday between July and September 2021. The education was performed by the RT supervisor and RT clinical specialists in the PICU. Questions were answered and clarifications were provided to team members by electronic communication and daily huddles during the first 2 months of each modification. Additional education was provided for all new RT staff members, PICU physicians, and advanced practice providers as needed. Rotating residents were provided education on the HFNC protocol at the beginning of their service block.

## Study Measures and Data Collection

HFNC duration in hours was used as the primary outcome measure, while PICU LOS, hospital LOS, and continuous albuterol duration in hours were used as secondary outcome measures. Pre-intubation noninvasive

ventilation (NIV) use (bi-level positive airway pressure), invasive mechanical ventilation (IMV) use, and 7-day PICU and hospital readmission rate were used as balancing measures. Analysis was conducted on data obtained from Virtual PICU Systems (VPS, Los Angeles, California). We used VPS to collect admission and discharge dates, age, sex, PRISM score, types of respiratory support, procedures (including intubation and ECMO cannulation). Data on race and ethnicity were collected from VPS but taken directly from the medical record (Cerner, North Kansas City, MO); race was defined by the National Institutes of Health (NIH) guidelines (21). We used Cerner to collect data on medications and other adjunctive therapies, including albuterol, magnesium sulfate, aminophylline, terbutaline and heliox. Patients requiring NIV and IMV were also excluded from analysis of the outcome measures but were used as balancing measures for the whole pediatric critical asthma cohort. The pre-implementation period was between January 2016 and September 2017. PDSA 1 period occurred from October 2017 through February 2019. PDSA 2 period occurred between March 2019 and June 2020, PDSA 3 period between July 2020 and September 2021, and PDSA 4 period occurred between October 2021 and May 2022.

## Statistical Analysis

QI macros add-in for Excel 2020.01 (KnowWare International, Denver, Colorado) was used to generate the statistical process control charts of the outcome measures. To adjust for the seasonal variation impacting the number of patients in the PICU with critical asthma, subjects were divided into groups of 10. The upper control limit and lower control limit were calculated as 3 standard deviations above and below the center line. We considered 8 consecutive points above or below the center line to represent a special cause variation, prompting a change in the center line. Subject demographics, clinical characteristics, and balancing measures were compared among five groups of subjects: the pre-intervention, initial post-implementation (PDSA 1), inclusion of patients on continuous albuterol (PDSA 2), rate wean increment change (PDSA 3), and after the HFNC holiday (PDSA 4) using Kruskal-Wallis tests for continuous variables and chi square tests for categorical variables. A multivariable linear regression model was constructed attempting to control for known confounders (race, sex, intermittent magnesium doses, and PRISM-III score) a priori to determine our interventions impacts on HFNC duration. Statistical analyses of the subjects' characteristics were performed using Stata17. A cutoff P value of  $<0.05$  was considered statistically significant. The Standards for Quality Improvement Reporting Excellence (SQUIRE) 2.0 Guidelines (22) were followed during the preparation of this manuscript (supplement table 1).

## Results:

A total of 410 patients were included in this study. Demographics and clinical characteristics were not different among the groups (Table 1). The use of adjunctive therapies did not vary among the groups (supplement table 2). Intravenous magnesium sulfate use was common in our cohort (86.8%); the vast majority received intermittent dosing with 1 patient receiving a continuous infusion. The number of doses of magnesium received were significantly different between study periods on univariate analysis. On multivariable analysis as magnesium doses increased length of HFNC also increased and thus the magnesium doses likely were not the driver of the decreased HFNC duration seen (supplemental table 3). Aminophylline was used infrequently (1.7%). Terbutaline and heliox were not used at all in this cohort.

For the primary outcome measure, HFNC duration decreased from 26.8 hours to 18.2 hours during PDSA 2 and it remained stable throughout PDSA 3 and PDSA 4 (Figure 2). For the secondary outcome measures, PICU LOS decreased from 41 hours to 31.8 hours during PDSA 2 and did not change during PDSA 3 and PDSA 4 (figure 3). Hospital LOS also decreased from 86.5 hours to 68 hours after PDSA 2 and remained stable throughout PDSA 3 and 4 (Figure 4). Continuous albuterol duration remained stable at 20.5 hours throughout the study (supplement figure 5).

Data on balancing measures is found in Table 2. IMV use declined throughout the study, from 9.2% during the pre-intervention period to 2.6% during PDSA 4. Seven-day PICU and hospital readmission rates were higher during PDSA 1 only ( $p=0.007$  and  $p=0.028$ , respectively) and afterward returned to 0-1.2% for the remainder of the study. The use of NIV and ECMO did not change significantly throughout the study.

### *Discussion:*

Our study demonstrates that a RT-driven HFNC management protocol can be safely implemented for pediatric critical asthma patients in the PICU. When used concurrently with a continuous albuterol weaning protocol, it can reduce HFNC duration, PICU LOS and hospital LOS. This was done without increased use of NIV and IMV or a sustained increase in 7-day PICU and hospital readmission rates.

The use of HFNC has become more common in PICUs over the course of the last two decades, and its efficacy in other similar disease processes such as bronchiolitis has been well established (23,24). In critical asthma, it has been shown to be safe, but limited data has not shown significant clinical benefits or decreased length of stay with its use (25,26). Many physicians utilize HFNC as a delivery mechanism for aerosolized medications such as continuous albuterol, which is shown to be effective at lower levels of HFNC (27). It is possible that despite clinical improvement, patients remained on HFNC to facilitate continuous albuterol delivery, which could help explain why there was not a decrease in duration of HFNC in PDSA 3 and 4.

There are other therapies used in the treatment of pediatric critical asthma aside from inhaled beta agonists. Steroids have long been a mainstay in treatment (28,29). Other therapies, such as magnesium sulfate, aminophylline, and terbutaline have had mixed results (30-32), and because of this, institutions tend to have different protocols for management of critical asthma. In our study, there was no increase in the utilization of other adjunct medications which might affect our outcome measures. It would be useful to have more definitive guidelines on the use of adjunctive therapies in pediatric critical asthma in the future to improve outcomes.

There is concern that with widespread use of HFNC in other disease processes, hospitalization costs have increased (7,8). In many hospitals, HFNC is used exclusively in the PICU which could be a driver of the increased cost. Concerns have been raised regarding the environmental impact associated with increased use of HFNC related to carbon emissions (33). While we recognize HFNC as an important respiratory support modality in many disease processes, it is important to be judicious in its use. Often, patients in respiratory distress are placed on HFNC in the emergency department as it is a quick and relatively easy way to provide respiratory support. However, a patient may rapidly improve in the PICU and no longer require HFNC treatment, but this goes unrecognized by the care team because of higher acuity patients, which leads to PICU and hospital stays, higher costs and increased environmental impact. Standardization of care, such as RT-driven HFNC management protocols, can help mitigate these issues.

There was no increase in adverse events in patients with critical asthma with the implementation of the HFNC management protocol and its subsequent modifications. During PDSA 1, there was a small but statistically significant increase in PICU and hospital readmission with return to baseline low levels in subsequent PDSA cycles. The rate of IMV decreased during the study. A similar study on the utilization of a HFNC management protocol in patients with bronchiolitis showed a similar pattern (12). This could be due to increased provider comfort with utilizing HFNC and other noninvasive respiratory support modalities or related to improvement in the care of patients with critical asthma in general. While previous studies have shown that HFNC decreases IMV rates in other disease processes such as bronchiolitis (23,24), this is less clear in critical asthma.

This study has several limitations. This was a single center quality improvement project, which may limit its generalizability to other centers that have different practices for treatment of critical asthma. While the PASS is a validated measure, the Riley Hospital Respiratory score is not, though it is similar to other scoring systems used in other studies (34-36). Like many other PICUs, RT staffing was limited at times which may have led to increased length of HFNC due to other more acute needs. In addition, other factors can influence PICU and hospital LOS, such as ward bed availability, nurse staffing, and social issues that prevent timely discharge. These factors are difficult to monitor and are outside the scope of this study. Finally, our protocol did not include a standardized criteria to start HFNC. Given the national trend of trading conventional oxygen therapy via facemask with HFNC in pediatric critical asthma (37), future interventions can aim to standardize the HFNC initiation in emergency rooms and PICUs.

## Conclusion:

An RT-driven HFNC management protocol was successfully implemented in pediatric patients with critical asthma and led to improvement in patient centered outcomes without adverse events.

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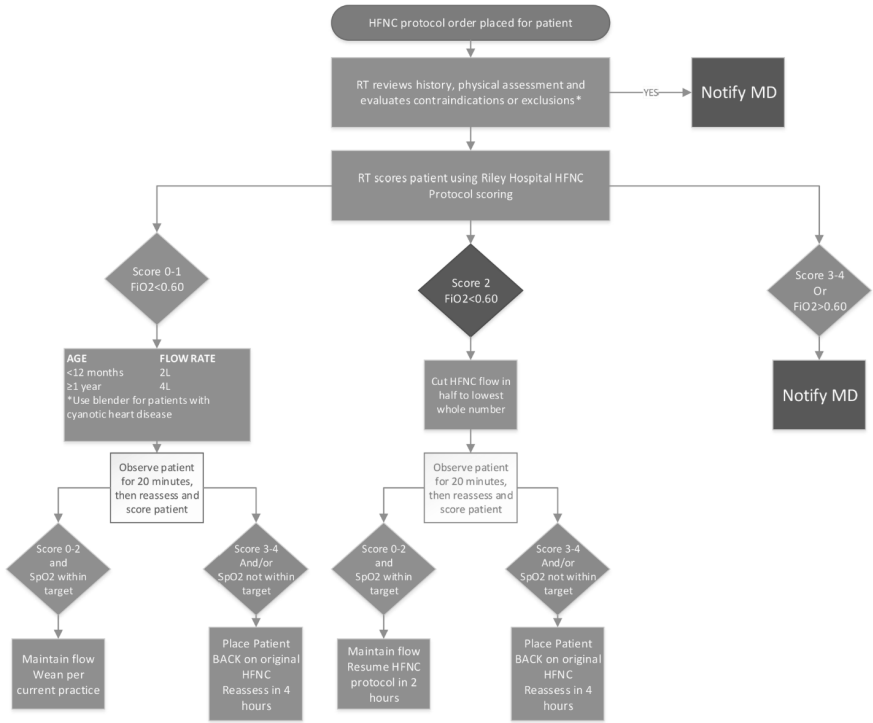
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Figure 1: HFNC holiday protocol



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Figure 4: X-bar control chart for length of hospital stay. Solid line (CL) denotes center line, lines above and below show upper and lower control limits. A change in the center line indicates special cause variation. Each group on the X axis consists of 10 patients. 1. Original HFNC management protocol implementation (October 2017); 2. Allowing continuous albuterol and HFNC to be weaned simultaneously (March 2019); 3. Adjusting HFNC wean rate (July 2020), 4. HFNC holiday (October 2021).

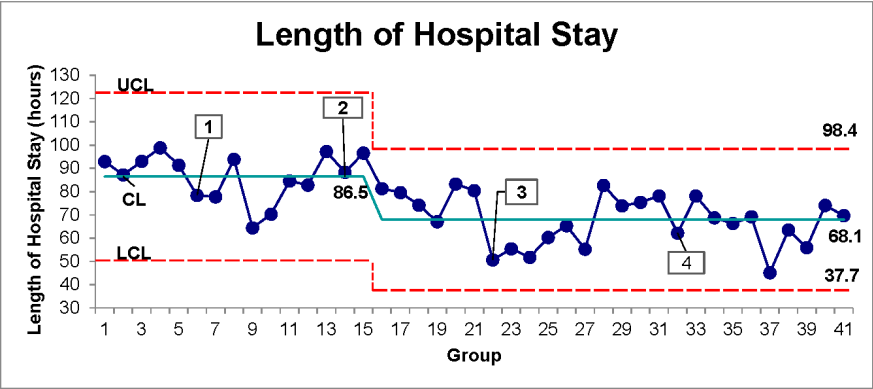




Figure 2: X-bar control chart for HFNC duration. HFNC = high flow nasal cannula, solid line (CL) denotes center line, lines above and below show upper and lower control limits. A change in the center line indicates special cause variation. Each group on the X axis consists of 10 patients. 1. Original HFNC management protocol implementation (October 2017); 2. Allowing continuous albuterol and HFNC to be weaned simultaneously (March 2019); 3. Adjusting HFNC wean rate (July 2020), 4. HFNC holiday (October 2021).

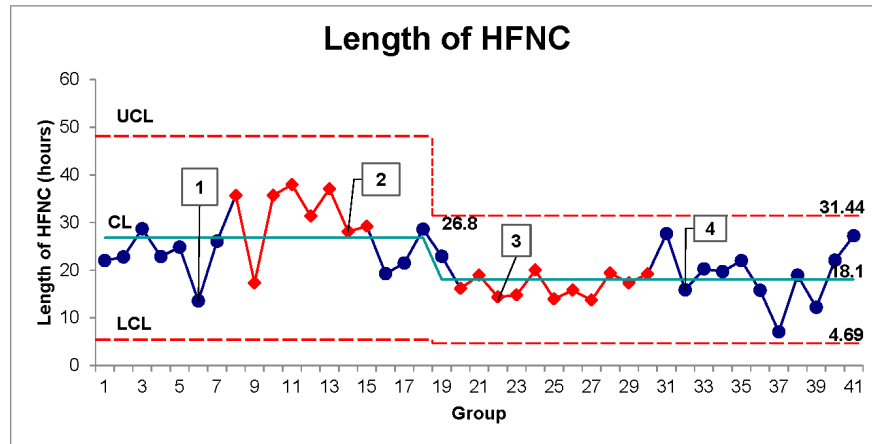
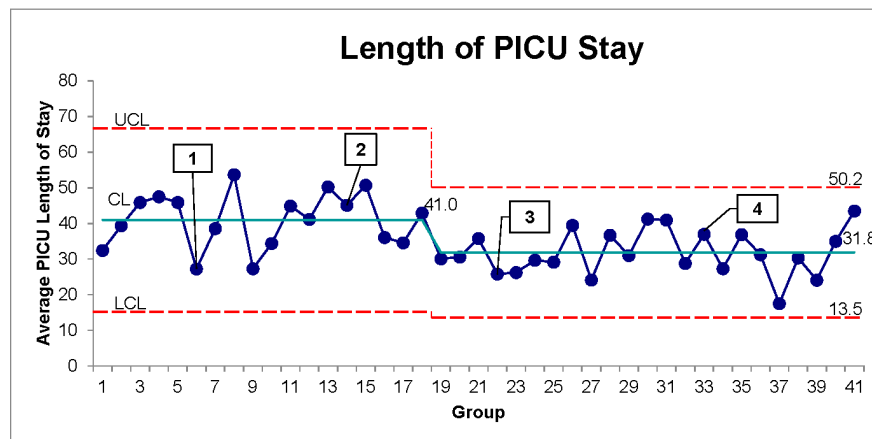


Figure 4: X-bar control chart for length of PICU stay. Solid line (CL) denotes center line, lines above and below show upper and lower control limits. A change in the center line indicates special cause variation. Each group on the X axis consists of 10 patients. 1. Original HFNC management protocol implementation (October 2017); 2. Allowing continuous albuterol and HFNC to be weaned simultaneously (March 2019); 3. Adjusting HFNC wean rate (July 2020), 4. HFNC holiday (October 2021).



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